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On-board OBD-2 Analyser

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The final product

As announced by our Publishing Plan printed on the Sneak Preview page every month, the focus in this issue is very much on PCB production techniques. Elektor Electronics PCBs are famous the world over for their quality and consistent appearance. Sure, they're also a tad expensive compared to what the competition are supplying but then the quality and finish are vastly superior.

Here at Elektor, the change from manual artwork design using masking tape and photographic reproduction techniques to an 100% PC-driven process was gradual, and took place in the early 1990s. The use of a PC to draw a schematic and then run a PCB design program was not forced or even 'suggested' by our governors at the time. In fact, some of the younger lab designers at the time started to discover the advantages of the PC route for themselves, eventually supplying files instead of drawings to their colleagues in the PCB design department. Others stuck to pencil, paper and rubber with equally good results particularly in RF and space critical designs. No matter how the final artwork was produced, we never actually mass-produced those famous Elektor circuit boards — this was always farmed out to PCB manufacturers. We did, however, handle the storage and packaging of what must have amounted to hundreds of thousands of those blue and green boards. Also, to this day we have our own PCB etching and drilling facilities. These are used to make prototypes and one-offs of any board we're proud and happy to have kept single-sided (not too many these days, thanks to the micros). I do recall the excitement in the lab and editorial offices about 15 years ago when a parcel arrived containing 500 or so boards for a recently published project. At last, the proud designer was able to see the fruit of all his design efforts. More importantly however, readers all over the world were more than satisfied with superbly produced circuit boards with a component overlay and silk screen finish!

Today, there is still the satisfaction not only of publishing these wonderful designs and hearing from you but also of holding a perfectly machined printed circuit board with an Elektor production number printed in a corner.

Jan Buiting, Editor

36 Onboard OBD-2 Analyser



International R8C Design Competition
great prizes - easy participation
page 14

**WIN &
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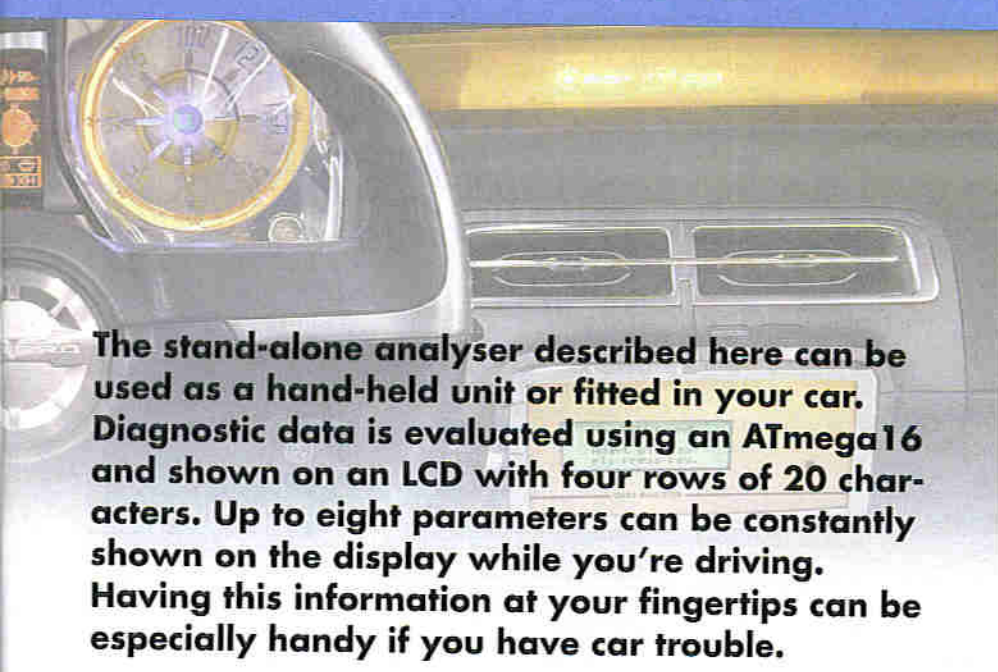
24 PCB Production in the Fast Lane

Once the design of a circuit has reached the point where the PCB CAD data file has been produced, a physical board is usually wanted as soon as possible so that a one-off unit or laboratory prototype can be assembled and tested. In this article we look how to choose between the various alternative routes to manufacture and survey their advantages and disadvantages.



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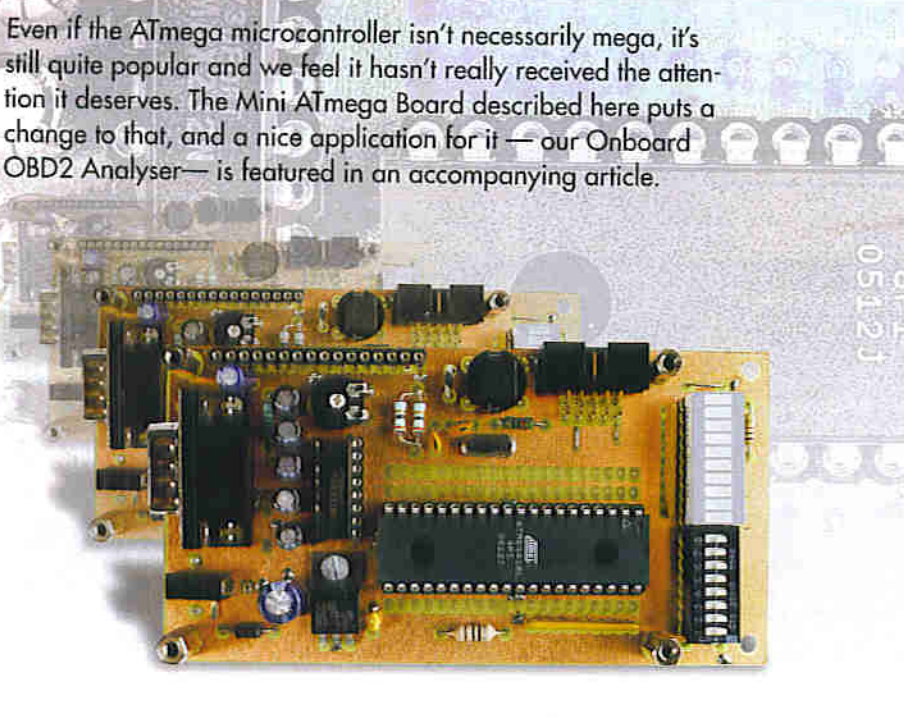


The stand-alone analyser described here can be used as a hand-held unit or fitted in your car. Diagnostic data is evaluated using an ATmega16 and shown on an LCD with four rows of 20 characters. Up to eight parameters can be constantly shown on the display while you're driving. Having this information at your fingertips can be especially handy if you have car trouble.

68 Electric Fence Energizer

Are you bothered by stray cats and dogs prowling and digging in your garden? Or does your own pet require strong persuasion to stay within a restricted area? This electric fence generator may well be the answer to your problems. A simple generator built around a 555 timer and an old ignition coil are sufficient to build a suitable circuit at a small outlay.

30 Mini ATmega Board



Even if the ATmega microcontroller isn't necessarily mega, it's still quite popular and we feel it hasn't really received the attention it deserves. The Mini ATmega Board described here puts a change to that, and a nice application for it — our Onboard OBD2 Analyser — is featured in an accompanying article.

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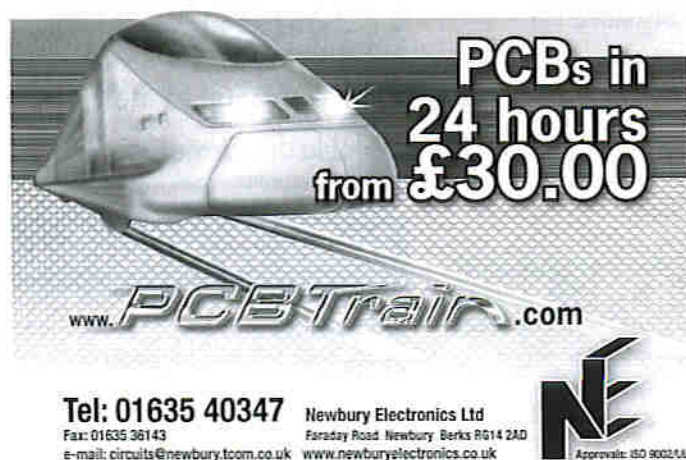
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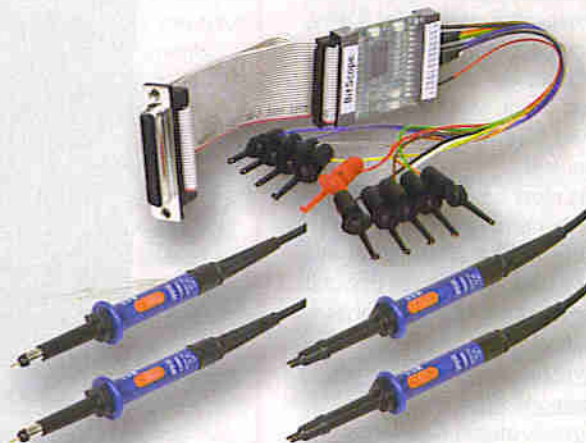
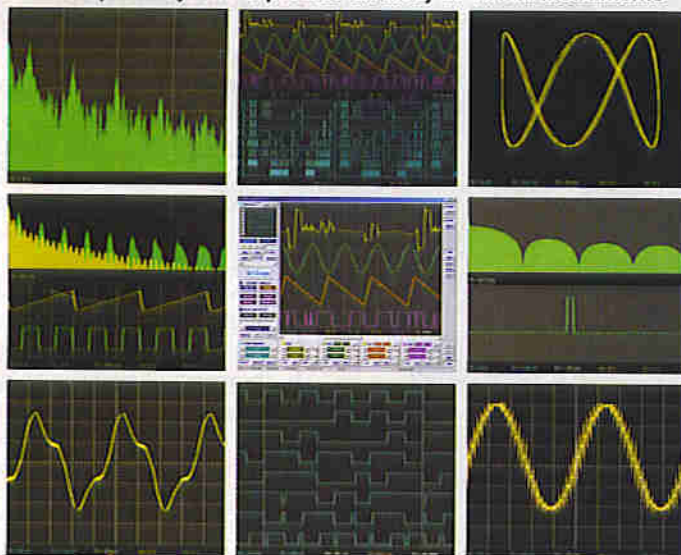
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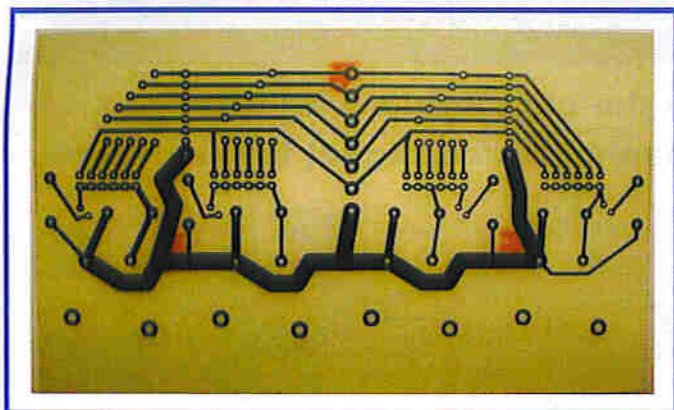


BitScope's integrated design uses standard oscilloscope probes and a growing range of custom probes to provide functionality equal to instruments many times the price.

BitScope plugs into third party software tools and has an open API for user programming and custom data acquisition.

BitScope DSO software for Windows and Linux

www.bitscope.com



Direct toner method

Hi Jan — I've been a subscriber for many years (I think since 1985) and I keep finding your magazine interesting and useful. However, I do have one suggestion regarding PCBs. Not living in a country in which have offices, I've always had problems with getting PCBs, since ordering from abroad is kind of complicated in my country (okay, I understand we're in the EU, but still...). Recently, I discovered a technology for making my own PCBs, which is very useful and quick: the toner transfer technique.

Maybe you've heard of it — basically it's just printing PCB to photo paper using a laser printer, transfer toner to the board using an ironer or laminator, etch and voila! Okay, choosing the right paper is difficult, but once you've figured it out, you have a finished PCB in less than 10 minutes!

This must be useful info for all home hobbyists, so maybe you should consider publishing a detailed article about it. Here is one link about the method:

www.fullnet.com/u/tomg/gooteepc.htm

There is also a dedicated group on Yahoo:

http://groups.yahoo.com/group/Homebrew_PCBs/

For your information!

Pavel Veider (Slovenia)

Thanks Pavel for the interesting email which are happy to reproduce here for the benefit of other readers. It's no coincidence as this issue is on 'All Things PCB'.

Horn loudspeaker turns 16

Dear Editor — we have constructed a matching pair of horn loudspeakers as published in *Elektor Electronics* magazine in May 1990 (pages 20-23). We have recently tested the speakers with a frequency analyser and found the low frequencies roll off at around 315 Hz, somewhat higher than expected and higher than the response indicated in Figure 2 of the article. Are you able to provide clarification of the following:

1. In Fig. 2 of the article there are two response curves. Which one is the measured response of this unit? What is the other curve for? This figure isn't referred to in the article.

2. Have there been any modifications or amendments to this design submitted or published that might answer our problem with lack of low frequency response?

Any suggestions or information would be very much appreciated.

Julian Weir (New Zealand)

We do not know how you did the measurement, but this design of a horn loudspeaker must give a low frequency roll off at about 50 Hz. The measurement in Figure 2 shows: (a) the frequency response of the complete unit at a distance of 1 m, with superimposed a second curve showing the pressure right in front of the horn. You should add these two to get an impression of the total frequency response. Drawing (b) shows the impedance curve of the complete loudspeaker system.

With a low frequency roll off at about 300 Hz you should hear no bass response at all when playing music and we cannot imagine that's the case. Something else must be wrong, for instance a wrong value for a filter component (the coil in series with the woofer). Also, the choice of the right woofer is important. I assume you have not used the original McFarlow speakers, since they are not available anymore. You have to use a speaker with the same Thiele-Small parameters, otherwise the coupling of the speaker to the horn will not be correct and you do not get enough bass output.

(Mr Weir replies) The horn response was measured at 1 m from the front (on-axis) and at differing heights (in front of the mouth, and in front of the drivers etc.) with a receiving level of about 80-90 dB. I have definitely heard a distinct lack of low frequencies: while there are some low frequencies, they are rather quiet. They can be heard when I place my head inside the opening.

The horns were built by my dad about 9 years ago. We will have a look at the filter electronics first to eliminate if that is the problem, then look into the drivers themselves. You are right, dad did not put the same McFarlow drivers in. He put in a 60 W (rms) 10" driver from Altronics Australia, as per the following web site:

www.altronics.com.au/index.asp?area=item&id=C3065

He would have researched the specs of the McFarlow and found one that he thought would have matched at the time, but we will have a re-look into that too. Do you have any thoughts off-hand that you can give regarding the suitability of this driver compared to the McFarlows originally specified?

I take it there have been no revisions of the design or discussions/commentaries on the final speaker?

Many thank for you help. It is very much appreciated.



Corrections & Updates

Simple Rechargeable AA Cell Characteriser

April 2006, p. 28-31, 050394-1

Resistor R3 is not shown in the circuit diagram. R3 is a 10-k pull-up resistor between the gate of T1 and the +5 V supply rail. It is present on the printed circuit board. R4 is a leaded component, not an SMD as suggested by the parts list.

Just after printing this article a problem occurred with the software supplied by the author. For this software to run, the user's PC must have Microsoft Java installed. For various reasons Microsoft is no longer allowed to use the name 'Java' and the relevant program is no longer found on the Internet (but Google for MSJAVx86.exe and you will still be able to find it).

No problems are usually encountered on PCs running Windows 95 or 98 as MS-Java will be resident and the program AA-CELL msjava.ZIP may be run without problems. The author has adapted his software to avoid the use of MS-Java. This requires changes to the installation. The following steps are recommended.

1. Install the 1-Wire drivers including .NET support (note when to actually connect the circuit, this is indicated during the installation; start without the circuit connected to the USB).

http://files.dalsemi.com/auto_id/licensed/install_1_wire_drivers_v400.msi

2. Download Microsoft .NET Framework 2.0 redistributable package and install it (heft file at 23 Mbytes)

<http://www.microsoft.com/downloads/details.aspx?familyid=0856EACB-4362-4B0D-8EDD-AAB15C5E04F5&displaylang=en>

3. Download Microsoft Visual J# 2.0 Redistributable Package and install it.

<http://www.microsoft.com/downloads/details.aspx?familyid=F72C74B3-ED0E-4AF8-AE63-2F0E42501BE1&displaylang=en>

4. Download the project software (AA-CELL dotnet.zip) from the Elektor website and install it.

5. Start → Programs → 1-Wire Drivers → start Default 1-Wire Net and select the DS9490 (USB) adapter.

6. Start → Programs → Maxim Integrated Products → AAccellchar

That completes the modified installation procedure.

In respect of electrical parameters the loudspeaker your dad used differs considerably from the one we specified for the project. Many readers asked us for a replacement type when McFarlow stopped the production, but it is pretty hard to find a similar type. The least we can do is give the main specs:

$Q_{TS} = 0.35$

$Q_{MS} = 2.6$

$Q_{ES} = 0.4$

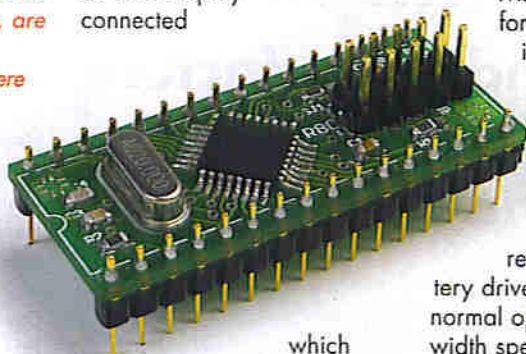
$V_{AS} = 66 \text{ l}$

$F_S = 40 \text{ Hz}$

The main things that must come close to the original specs, are QTS and VAS.

By the way, no corrections were published for this project. It was a successful design, not really high fidelity, but very good given its relatively low building and components costs.

Veroboard and just connected the Avit data lines direct to the microcontroller pins. I used the Avit 5V and ground lines to power the R8C from the PC, again just a direct connection. The system worked first time, the only problem I had was when I tried to download a second program and found that I needed to check the box marked "erase before programming" (or words to that effect) in the FDT software. I also have a 4x20 character LCD display connected



which seems to work ok, though I didn't try using the backlight as I don't know how many mA I have left!

I may install a switch in the power line so I don't have to switch off the PC or unplug the cable when I need to power down the R8C. So far so good!

Keep these excellent projects coming!

John Bishop (UK).

Thanks John and also Adrian Verity of Avit Research; there's another fine example of how quickly solutions can be found via our online Forum.

Energy recovery

Dear Editor — I was interested to read in 'Design Tips', *Elektor Electronics*, March 2006, the piece submitted by Peter Lay, describing how to recover energy from a relay coil during switch off.

Many years ago performed (very amateurish) experiments using this technique in a motor circuit. The idea was to get an idea of how much energy could be recovered from a battery driven motor during its normal operation under pulse width speed control.

Obviously the energy recovered would be on-going as the motor was running. My circuit was almost identical to that described by Mr. Lay, with the exception that the motor was in place of the relay shown. The transistor was of course driven by a variable frequency square wave.

I was able to demonstrate an amount of energy recovered by the voltage appearing on

the capacitor, although this did not indicate a very large amount. However my limited knowledge and practical skills prevented me pursuing the experiments. Would there be any advantage in this sort of idea in attempts to extend the life between charges of batteries driving motors? (my thoughts at the time were of electric vehicles). Perhaps some of your readers could pass some comments?

David Clenton (UK)

Suggestions and comments invited, please send them to the Editor.

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New dimension to solid state lighting applications

OPTEK Technology has introduced one of the industry's brightest single-source packaged visible LED assemblies. Designated the OPTEK Lednium Series, the 10-W package offers a full 120° viewing angle for its array of amber, blue, green, red, or white LEDs.

OPTEK's Lednium Series devices are claimed to achieve an output of up to 330 lumens with nine 1-watt LEDs mounted in an anodized aluminum package just 1.3 inches square, with a board mounted profile of less than 0.5 inch.

Conventionally-packaged LED arrays with comparable light output often require as many as 12 1-W LEDs in configurations up to 8 inches in diameter, which typically consume more power.

The wide viewing angle and increased brightness are critical

features for lighting design engineers as they begin to incorporate solid state light sources (LEDs) into applications such as automotive interior and exterior lighting, indoor and outdoor electronic signage and displays, as well as architectural lighting and general lighting applications.

The OPTEK Lednium Series LED assemblies also provide different parallel-serial connections that enable the operation of 3, 6 or

all 9 of the mounted LEDs, enabling design engineers to vary the light output and power consumption.

OPTEK's Lednium Series devices are available in amber (595 nm, 330 lm); blue (467 nm, 60 lm); green (524 nm, 290 lm); red (624 nm, 247 lm); and white (250 lm). All colours feature a full 120° viewing angle in water clear lenses. In development are other visible, as well as UV and IR wavelengths and package configurations.

DC forward current is 1.05 A, with peak pulsed forward current of 3 A. Typical forward voltage characteristics range from 6.3 V to 9.25 V (colour-dependent), and reverse voltage for all devices is 15 V.

Maximum allowable junction temperature is 130°C (average thermal resistance junction-to-board is 5°C/W), and the

operating temperature range for the device is -50°C to +80°C.

OPTEK Lednium Series products are stocked by OPTEK's distributors in the Americas, Europe and Asia.

OPTEK Technology,
1645 Wallace Dr., Carrollton,
TX, 75006, USA.
Tel. (+1) 972-323-2200.
www.optekinc.com/led_pr1.asp.

(057111-1)

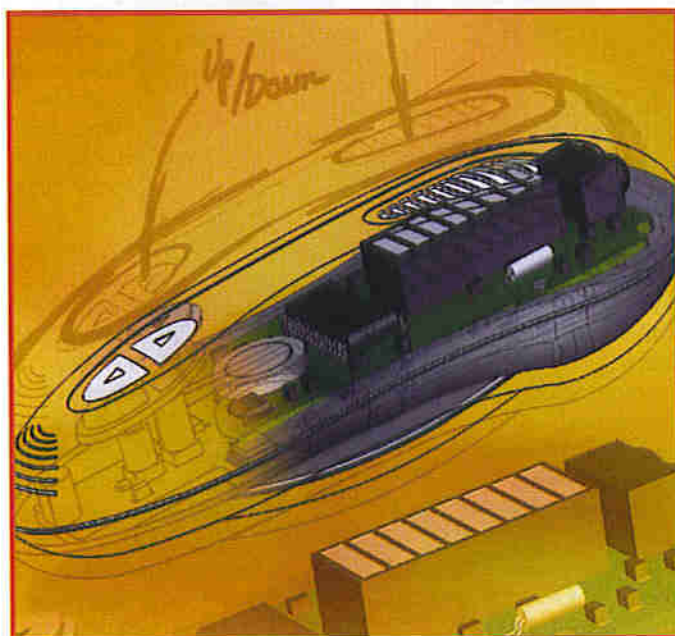


Lascar for design and manufacture

Lascar Electronics Ltd. Now offers a custom design and manufacturing service that provides its customers with an effective route to take projects from conception to market in a timely and cost-effective manner.

Lascar's experienced engineering design and development team have expertise in many aspects of electronics, mechanical and software design — providing the flexibility to engage all elements of the design process. This includes the design and development of custom LCD and LED displays, circuit design, PCB layout, 3D modelling and writing PIC and Windows based software.

While full control of design and manufacture is retained in the

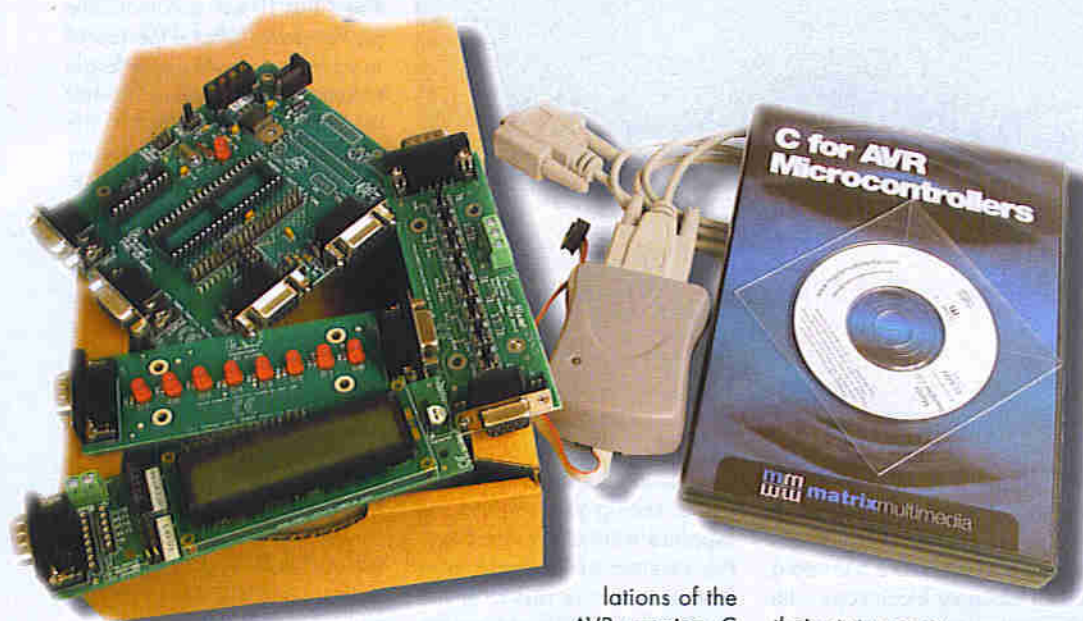


UK, Lascar's service offers a straightforward route to Far-Eastern manufacture and the cost benefits associated with them. Many types of manufacturing techniques are employed including COB, COG, SM, Plastic Injection Moulding, Metal Casting and Sheet Metal fabrication processes. All manufacturing processes undertaken by Lascar are carried out to BS ISO 9001:2000.

(057111-5)

Lascar Electronics Limited,
Module House, Whiteparish,
Salisbury, Wiltshire SP5 2SJ.
Tel. (+44) (0)1794 884567,
Fax (+44) (0)1794 884616.
Internet:
www.lascarelectronics.com

Learn to program AVR microcontrollers in C



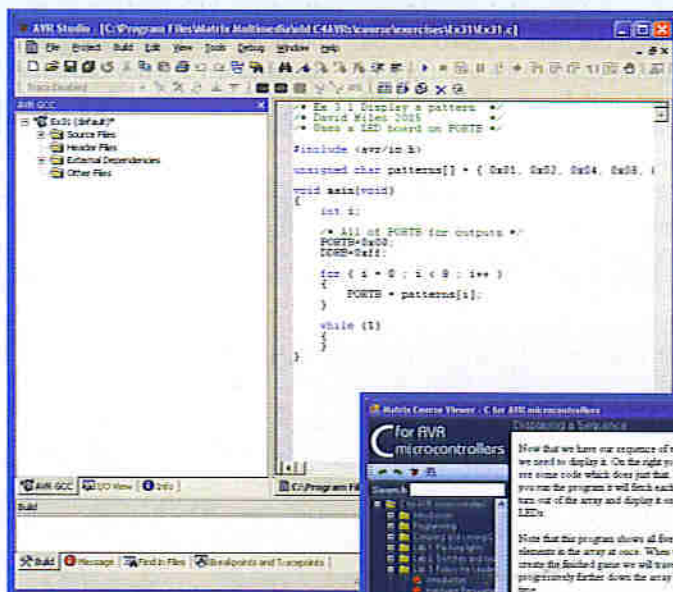
If you have always wanted to learn C programming for a microcontroller but have struggled with books and manuals on the subject, then this kit could be what you have been waiting for. The kit is based on our popular E-blocks™ system for rapid prototyping and learning. The concept of E-blocks is simple: each E-block consists of a block of electronics you would find in an electronic system: a processor board, a switch board, keypad, USB interface etc. To make an electronic system you simply snap the appropriate E-blocks boards together and develop the software to make the system run to the specification. Whilst developing the hardware system is relatively easy, the software can be the difficult part – and that's where the C for AVR microcontrollers CD ROM comes in.

The C for AVR Microcontrollers CD ROM fulfils several needs of those wanting to learn C programming for the AVR and for those who want to develop projects.

Firstly the CD ROM includes a full course in C programming. The course is screen-based and makes full use of the computer as a medium for learning: it contains a series of computer simu-

lations of the AVR running C code. This is a great way of learning C, because the simula-

their status as an input or an output, and their logic level – where logic 1 is



tions allow you to see the effects on the AVR device as each line of C code is executed, and you can easily understand what is going on. The screen image shows the Virtual C machine. Referring to the diagram: the top part shows you the C program under discussion, underneath that in cyan you can see the variables, which change as the program runs, below that you can see the port A and B I/O lines with arrows that show

indicated by a red 'LED'. Below the I/O lines are the critical registers: the data direction registers and their hex input and output values. Controls on the right hand side allow you to run the

program or step through it line-by-line and see the logic levels of the I/O lines change.

Secondly the CD contains a copy of the AVR Studio development environment which has a fully working licence-free C compiler embedded into it. You can access AVR studio – pre-loaded with the relevant program – directly from the CD by clicking on hyperlinks in the tutorials. The learning methodology is really complete: you read the text on-screen, view the program working on the Virtual C machine, load AVR studio, and then compile the program and send it to your hardware.

Lastly the hardware contains an Atmel AVR programming board with In System Programming module a board containing eight LEDs, a board containing 8 switches, and a 2-line 16-character LCD board. This is most of what you need to get started and the AVR programming board is compatible with the whole range of additional E-blocks boards should you want a keypad, prototype board, IrDA board or other peripheral.



The Elektor Electronics Easy AVR Kit is available now from the Elektor SHOP, check out details and price at www.elektor-electronics.co.uk

(0571 11-4)

Network Cable Analyser gets an intelligence boost!

Peak Electronic Design Limited have launched an enhanced version of their Network Cable Analyser the Atlas IT (model UTP05), designed and made in the UK.

The Atlas IT has always had the unique ability to analyse many types of RJ45 based network cabling, including Ethernet, Token Ring, Patch cables and Crossover Cables. The connection pattern of the cables is automatically recognised and displayed on the unit's display as well as confirmation of the full connection pattern.

Now the Atlas IT has been enhanced with cable definitions of 8 more cable types, including Cisco terminal cables, Linn Audio network cables, Ethernet Economisers, 4 line crossovers, voice/data cables and many more. Additionally, for the first time ever, the Atlas IT can now recognise the cable type even if there are connection faults (such as missing connections, swapped lines or other errors). It



will display the cable type and highlight any lines that have errors.

The Atlas IT hardware has had a boost too, now it can cope with connection to live comms systems and even withstand the high telephone ring voltages (upto 80 V) associated with mixed voice and data cabling. Using the Atlas IT could not be easier, connect the main unit at one end of your cable run and the miniature (18 mm cube) ter-

minator at the other end. For socket testing you can use the supplied mini patch leads too. Press the test button and after a few seconds the results of the analysis are displayed on the clear alphanumeric display. If you use the unique Identified Terminators, the Atlas IT will identify the cable run for you too, allowing the easy testing and identification of many cable runs (upto 24) without having to make lots of trips to swap ter-

minators.

The Atlas IT will automatically power down after a period of inactivity, so you'll never forget to switch it off. Measuring just 103mm x 70mm x 20mm, the Atlas IT fits in the palm of your hand or could even happily dangle from a network socket! When it's not in use, it can be stored safe and sound in the supplied custom machined carry case along with your accessories, terminators, cables and a spare battery.

The Atlas IT is available from many distributors including Farnell and Maplin as well as directly from the manufacturer for £89.00 fully inclusive of UK delivery and VAT.

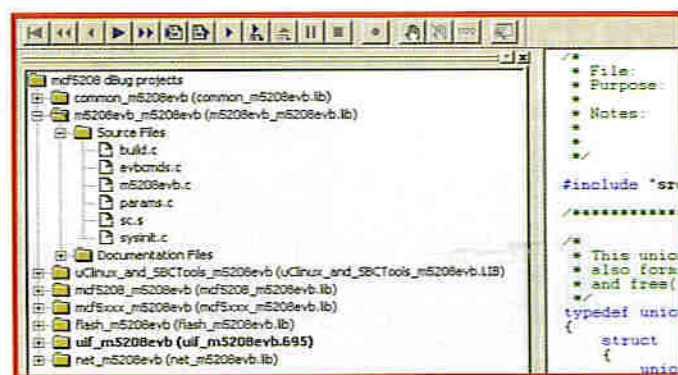
Peak Electronic Design Ltd.
Atlas House,
Harpur Hill Business Park,
Buxton, Derbyshire SK17 9JL.
Tel. 01298 70012,
Fax. 01298 70046.
www.peakelec.co.uk

(067111-2)

Coldfire suite embraces Freescale MCF5207 and MCF5208

Crossware has enhanced its ColdFire® Development Suite by adding support for Freescale Semiconductor's MCF5207 and MCF5208 ColdFire microprocessors. This support includes a utility that allows programmers to integrate Freescale's dBug ROM monitor software instantly into the Crossware development environment allowing developers to be debugging this firmware within minutes.

In addition, Crossware has added support for 64-bit integer arithmetic to its ColdFire C compiler as this is becoming an essential requirement for modern embedded systems. 64-bit integer arithmetic is used extensively, for instance, for checksum calculations in Freescale's compressed audio reference software.



The MCF5208 is a high speed microprocessor based on the V2 ColdFire Core. It includes a wide range of connectivity peripherals, an integrated DDR SDRAM memory controller and an enhanced multiply and accumulate unit (eMAC). Distributed clocking allows the on-chip modules to be separately enabled and disabled which, in conjunc-

tion with a low power clock divider, makes a low power implementation particularly practical.

Many developers wish to use Freescale's dBug ROM monitor software as a starting point for their own application. This is particularly easy with the latest Crossware release because a new utility allows the complete

dBug source tree and build settings to be imported, in a matter of seconds, into the Crossware graphical development environment. Developers can complete a build and download cycle within minutes of unzipping the Freescale files. Additionally Crossware's FireFly USB BDM (background debug mode) interface allows rapid download of the firmware into flash.

Crossware's ColdFire Development Suite allows developers to create, build and debug their ColdFire programs both with and without hardware. The totally integrated, user-friendly environment accelerates the development process and significantly reduces new product time-to-market.

(067111-7)

www.crossware.com

Dual-tuner DVB-T PCI Express solution for the living room

Micronas offers PC OEMs and system integrators production-ready DVB-T design for home theaters.

At CeBIT 2006 Micronas launched the MicPython™2H-X, a dual-tuner DVB-T PCI Express® card for home theater solutions. A universal antenna connection lets the user watch and record analogue, digital, and future HDTV signals without worrying about complicated cable connections or even switching antennas. MicPython 2H-X works with Windows XP Media Center and other third-party applications, guaranteeing ease-of-use. Micronas will showcase MicPython 2H-X for the first time at CeBIT in Hanover, Germany from March 9 to 15, 2006.

Home theatre systems must be small and unobtrusive, while delivering picture quality good enough for ever larger screens. MicPython 2H-X's small size and



low power requirements mean the system enclosure is small and quiet. The company's extensive television expertise went into the design to ensure best picture quality. MicPython 2H-X uses the DRX 3975D demodulator, the nGene® APB 7202A PCI Express controller, both from

Micronas, and a MicroTuner™ MT2060 digital TV tuner from Microtune.

Micronas' nGene dual-channel multimedia PCI Express controller delivers the bandwidth needed for two TV channels up to HD, all in a single slot – eliminating potential bottlenecks that may

occur with two slots required by conventional PCI. nGene is certified by the PCI-SIG, the industry standard body for PCI Express technology, to be PCI Express 1.0a compliant. This certification guarantees that MicPython 2H-X is compatible with a wide variety of PC motherboards offering PCI Express x1 slots.

MicPython 2H-X and the ATSC-based MicViper™2H-X are the first members of a family of nGene-based reference designs supported by a common software model. The common software support across the family makes it easy to design world-standard products. MicPython 2H-X and MicViper 2H-X are complete, production-ready solutions. Both reference design kits are available now.

(067111-1)

www.micronas.com; www.dvb.org

TMD Technologies' guided transition to lead-free

Specialist UK electronics manufacturing company TMD Technologies Ltd (TMD) has appointed Dr Shubo Gao to implement the transition from the company's traditional to latest environmentally-friendly lead free soldering processes.

The new project is being undertaken as a Knowledge Transfer Partnership (KTP) between TMD and CRDM Research (Centre for Rapid Design & Manufacture), a Department of the Faculty of Technology, Buckinghamshire Chiltern University College (BCUC). The programme is funded by the Department of Trade and Industry.

Dr Shubo Gao, who has a degree in Electronics Engineering and 10 years of industrial experience in electronics assembly, will be responsible for the detailed planning and execution of the project, and will be based mainly at TMD's manufacturing facility in Hayes, West London, near Heathrow Airport.

She will be working under the



guidance of both TMD and David Jacobson, Professor of Materials at CRDM Research, BCUC, who is responsible for

overall supervision of the programme.

This important development is aimed at meeting the require-

ments of new 'green' EU legislation that bans the use of lead in soldered products, and which comes into force in July of this year. It will ensure that TMD's future manufacturing methods will be compatible with all components from the European Market tailored for lead free use – as well as those from other world markets that are currently not suited to lead free processes. The in-house programme will include the re-training of relevant TMD personnel in all aspects of lead free soldering technology. TMD Ltd. designs and manufactures specialised transmitters for radar and electronic warfare applications, power supplies and microwave tubes. It also produces a range of commercial amplifiers for EMC testing, medical and scientific applications.

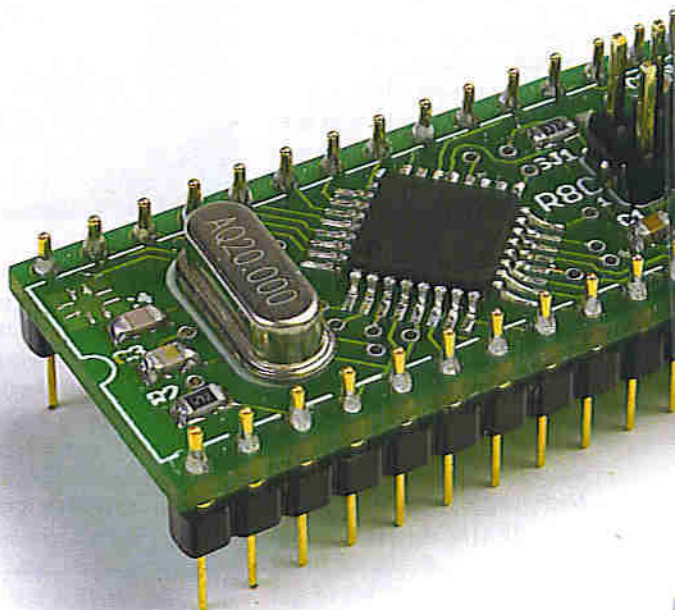
(067111-8)

TMD Technologies Ltd., Unit 3, Swallowfield Way, Hayes, Middlesex, UB3 1DQ, UK. Tel: (+44) (0)20 8573 5555. www.tmd.co.uk

International R8C

1st Prize: your design goes in

The R8C Service Page and the R8C Forum topic on our website clearly show that the 16-bit Tom Thumb Starter Kit from the February 2006 issue is a great source of inspiration for readers' own experiments and applications. The free C Booklet supplied with the March 2006 issue was a further stimulus by presenting C programming for the little board. A great time, we thought, to launch a design competition and give the R8C project a further boost.



Microcontrollers are no longer the exclusive domain of professional designers and programmers. We estimate that about half the readership of *Elektor Electronics* are conversant with microcontrollers, and the percentage is sure to rise with the availability of our Tom Thumb R8C Starter Kit (costing just £ 8.30 plus P&P).

A 16-bit controller with great connectivity for peripherals, the R8C/13 from Renesas offers lots of possibilities for interesting applications that are easily thought of as going into mass-produced commercial products. After all, millions of R8C micros are in daily use all over the world, mostly in consumer electronic equipment and automobile electronics. This circumstance really triggered us to organise a design competition around our successful R8C micro and offer full commercialisation of the winning entry as the first prize. The lucky winner will receive royalties over the turnover realised by the product. However there are lots of other great prizes to be won!

The assignment

Develop a killer application for the R8C/13 microcontroller introduced in the January and February 2006 issues of *Elektor Electronics*. Both the Tom Thumb module (February 2006) and the R8C Prototyping Board (March 2006) may be used, but really any hardware configuration around the R8C is fine. The only condition is that **a microcontroller from the R8C series is used**.

There are no limitations or conditions for software tools, although we should add that for a publication of your

design it would be advantageous that freely available tools have been used, i.e., any of the programs on the Starter Kit CD-ROM, or an Elektor free download. This recommendation is made to make sure that ideally the whole R8C community can reproduce your application through the magazine pages or the Elektor website.

What to supply

To participate in the competition, please **do not send us hardware or prototypes**. Instead, supply the following:

1. A short description of the functionality in Word, RTF or ASCII format.
2. Circuit diagram (excluding the R8C board) on paper by post or by email as a .jpg, .tiff, .eps or Acrobat file.
3. Source code or hex code file(s) of the R8C target software (on diskette or CD if sent by post).
4. Additional documentation you deem essential for an initial appreciation of your project (for example, images).

Where to send it to

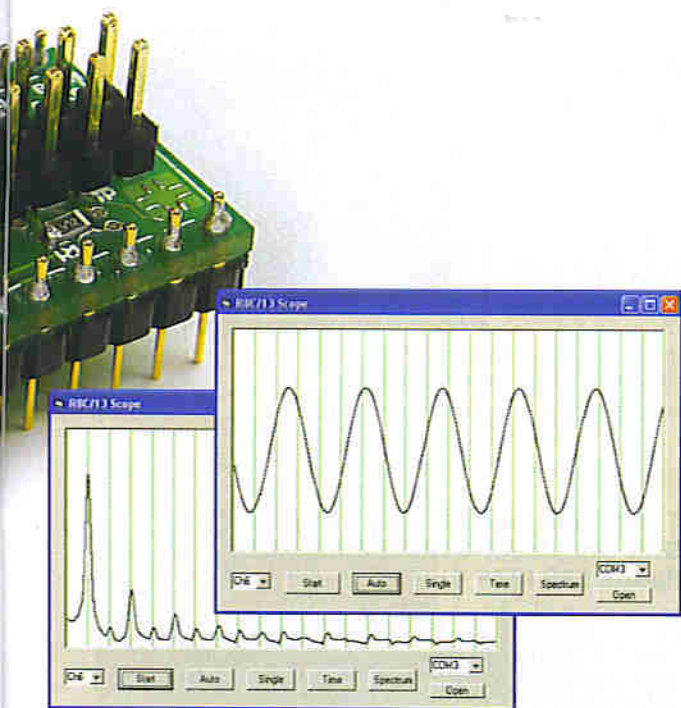
Please send your competition entry by email to

editor@elektor-electronics.co.uk

and use *R8C competition* as the Subject. Automatic sorting will be applied to incoming emails so please copy the subject exactly.

Design Competition

to production!



Alternatively, send the project by post to

Elektor Electronics R8C Competition
Regus Breniford
1000, Great West Road
Breniford TW8 9HH
United Kingdom

The Jury

The Jury consists of Elektor designers and editors, Mr Burkhard Kainka and Mr Günther Ewald (the authors of the January 2006 article) as well as several other R8C specialists and project contributors active in our R8C Forum and on our R8C Service pages. Mat Heffels, our International Editor in Chief, has been appointed Head of the Jury.

Winners

The winners of the competition will be announced in the **November 2006** issue. The decision of the Jury in respect of prize-winning entries is not open to discussion. The competition is not open to employees of Glyn, Renesas, Elektor Electronics, or publishing houses with a business relation to Segment b.v.

Publications

By participating in this competition, you agree to publication, in original or edited form, of all material you have

Special Prize

As is generally known, genius and lunacy go hand in hand. Consequently, not all competition entries can be measured with the same yardstick regarding real-life value, efficacy and the extent to which the project is 'finished'. That's why a **special prize** is offered for the **most creative project** we receive for this competition. The prize is also as creative as it gets: **An E-Blocks Easy AVR Starter Kit from Matrix Multimedia** with a value of £ 250 and a **Valve Experimenters Kit from AK-Modul-Bus** with a value of £ 65!



supplied in relation to the entry. The Jury decides which projects are published in *Elektor Electronics* magazine, and which on our website(s). **In addition to a prize, a remuneration of 75 pounds or 100 euros is paid per published page** (assuming an article size of five pages, that's £ 375 or € 500).

1st Prize

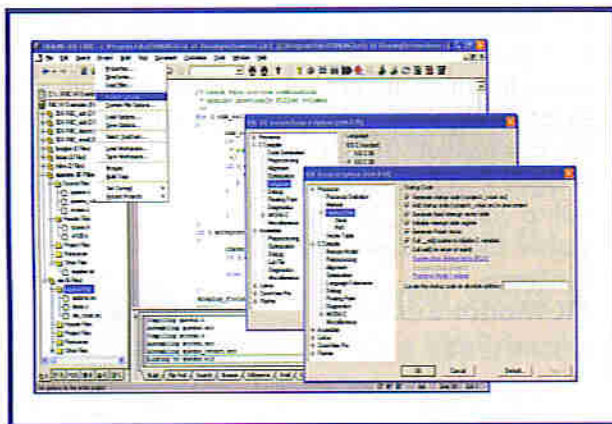
The First Prize is awarded to the R8C application that's best suited to production, marketing and sale through the Elektor SHOP (magazine and web) and/or Elektor's business partners, within the Publishers' abilities. The prize consists of royalty payments to the amount of 10% (ten percent) of the turnover realised by the winning project.



2nd Prize**TASKING M16C & R8C/Tiny Software Development Tools v3.1****Value: £ 2239 (3242 €)**

A complete software development toolset from Tasking, including Altium's Viper Compiler technology.

The ultimate for M16C and R8C software builders.

Info: www.tasking.com/products/8_16_bit/M16C/**Altium Europe GmbH** www.altium.com**3rd Prize****EAGLE Professional****Value: £ 975 (1392 €)**

Complete design suite for circuit board design (up to 1.6 m x 1.6 m, 16 signal layers, 99 schematics pages).

Product: 1 User, Layout Editor, Schematics Module, Autorouter Module.

CadSoft Computer GmbHwww.cadsoft.com**4th Prize****EAGLE Standard****Value: £ 480 (696 €)**

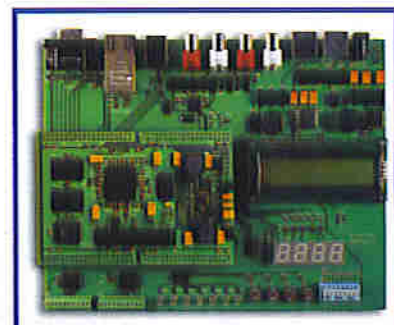
Complete package for PCB design (1 Eurocard, 4 signal layers, 99 schematics pages).

Product: 1 User, Layout-Editor, Schematics Module, Autorouter Module.

CadSoft Computer GmbHwww.cadsoft.com**5th Prize****Money prize: £ 350 (500 €)**The fifth prize is 350 pounds (or 500 euros) sponsored by **IPS-Presservertrieb GmbH**www.ips-pressevertrieb.de**6th Prize****Elektor Versatile FPGA Module & Prototyping Board****Value: £ 324 (469 €)**

Versatile FPGA Module with programming interface, cable and connectors, and the FPGA Prototyping Board.

Info:

Elektor Electronics March 2006.**Elektor Electronics (Publishing)**www.elektor-electronics.co.uk**7th Prize****ME 2-channel PocketScope DS1M12 with TESTEC double MF 312-2 probe kit.****Value: £ 259 (374 €)**

A mobile USB Mini Scope / Waveform Generator including 2 x TT-MF 312 test probe for 20 / 250MHz.

Reichelt Elektronikwww.reichelt.de**8th Prize****DK51 - Complete Starter Kit for SC11 and SC13 IPC@CHIP****Value: £ 219 (312 €)**

Comprehensive Starter Kit for your IPC@CHIP-application with DK50 Development Board, SC13 IEC, CoDeSys CD, Borland CD, serial cable and power supply.

Beck-IPCwww.beck-ipc.com

9th Prize

USB Logic Analyser ME ANT 6
Value: £ 199 (279 €)



Mobile, compact 8-channel USB Logic Analyser, ideal for mobile use in combination with a Notebook PC.

Meilhaus Electronic GmbH
www.meilhaus.de



10th Prize

MicroPLC Hardware

Value: £ 179
(257 €)

Kanis and Cadsoft's EAGLE-programmable PLC. Ready-to-use board with detailed documentation, power supply and accessories.

Design Bureau W. Kanis GmbH
www.kanis.de

11th Prize

PCB manufacturing
Value: £ 140
(200 €)

Voucher to above value for a PCB manufacturing order placed with PCB-POOL.

Beta LAYOUT www.pcb-pool.com



12th Prize

PCB manufacturing
Value: £ 140 (200 €)

One-off discount of the above amount (incl. VAT) on an online 'Plot&Go' or 'Verified' order.

Eurocircuits Bvba
www.eurocircuits.com



13th and 14th Prize

Wireless audio modules WA-TX-01 and WA-RX-01A
Value: £ 99

(140 €) each

These modules (transmitter and receiver) from Circuit Design enable a high quality wireless link to be created (e.g. for a cordless microphone).

Circuit Design www.circuitdesign.de



15th through 24th Prize

Renesas E8 Emulator

Value: £89 (128 €) each

The E8 enables serial synchronous debugging independent of quartz frequency and monitor.

Glyn www.glyn.com

25th Prize

Altium Live Design Evaluation Kit

Value: £ 79 (115 €)

The Altium Designer LiveDesign Evaluation Kit contains the LiveDesign Evaluation Board with FPGA (Altera Cyclone or Xilinx Spartan-3) and the Altium Designer Software (unrestricted 30-day licence).

Altium Europe www.altium.com

26th and 27th Prize

I/O Warrior Starter Kit

Value: £ 39

(57 €) each

Kit for IO Warrior Evaluation Board including software for Win, Mac, and Linux.

Code Mercenaries Hardware and Software

www.code-mercs.com



28th, 29th and 30th Prize

Elektor Electronics Voucher

Value: £ 35 (50 €)

Valid for all SHOP products supplied by the Publishers like books, CDs, ready-made modules, kits, software items and circuit boards.

Elektor Electronics (Publishing)
www.elektor-electronics.co.uk

Lead-free? No p

Felix Meckmann and Jens Nickel

The use of lead-containing solders will be severely restricted from the beginning of July 2006. This has far-reaching consequences, especially with regard to automated soldering.

We take a closer look.

Electronics is playing an ever-increasing role in all areas of daily life. As a consequence the number of discarded and redundant electronic appliances and components is continuously on the rise. The EU member states together generate over six million tonnes of electronic waste per year. Furthermore, many electronic and electrical appliances contain toxic substances such as lead, mercury and cadmium.

In 2002 the European Parliament and the Council of the European Union, representing the national governments, enacted two directives, 2002/95/EC and 2002/96/EC, which became known as 'RoHS' and 'WEEE' [1][2]. The directive on 'Waste Electrical and Electronic Equipment' puts liability on manufacturers to mark their appliances, to take old appliances back, recy-

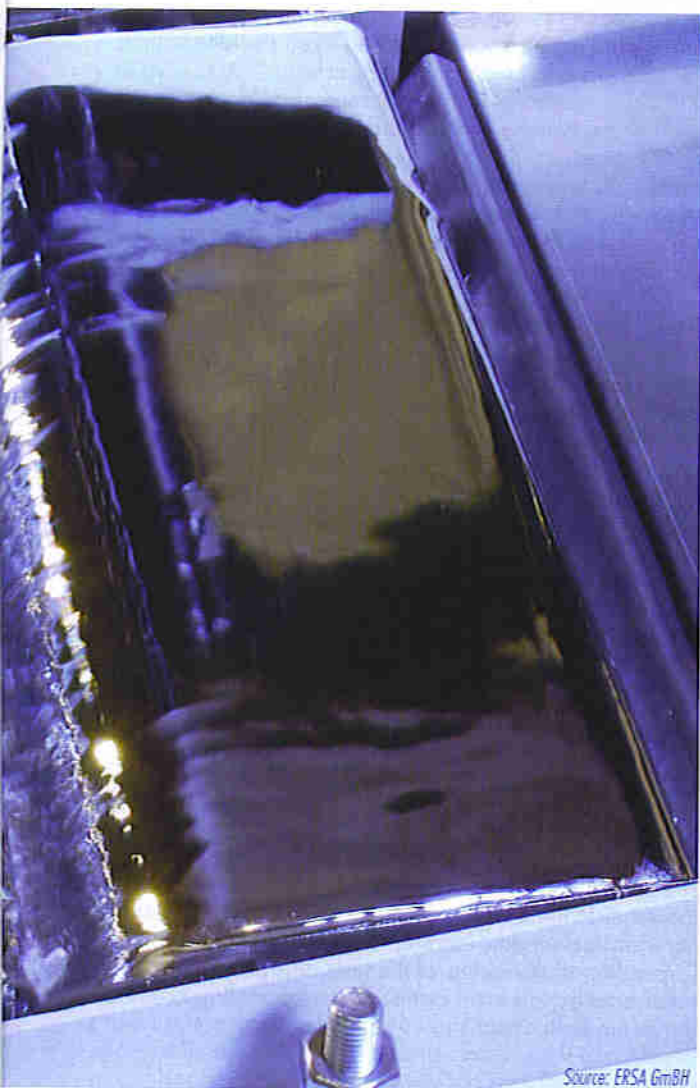


cle them as far as possible and prepare the residual waste for disposal [3].

The ban on the use of certain specified hazardous substances in the manufacture of new appliances will avoid damage to the environment and human health, and questions of disposal methods will arise. To this end the RoHS ('restriction on the use of certain hazardous substances in electrical and electronic equipment') regulations have been adopted, which restrict the use of specified hazardous substances. The regulations cover not only lead, which is an important constituent of solder and which is responsible to a large extent for its properties, but also mercury, cadmium and other substances used in such things as cables and enclosures. The various EU member states are transposing the directives into national law.

problem

Soldering in the RoHS era



Source: ERSa GmbH

The one part in one thousand limit

July 1st 2006 is a key date for developers and manufacturers of electronic equipment: this is when the ban on hazardous substances comes into effect. From this point it will no longer be permitted to bring 'onto the market' any electrical or electronic appliance which is not RoHS compliant, that is, which contains any of the proscribed substances. In order to make the purification and analysis of materials technically and economically feasible, thresholds have been set below which a material will be considered 'free' from a particular substance: for example, a solder containing less than 0.1 % lead by weight will be deemed 'lead-free' for the purposes of RoHS. These thresholds apply for all 'homogeneous' materials from which an appliance might be constructed. ('Homo-

geneous' means that the material can only be further decomposed by chemical, rather than mechanical means.) Examples are the metal used for an enclosure, copper printed circuit board tracks, solder and so on. It is therefore necessary that not only the equipment, but also the boards and components used in it, are RoHS compliant. If, for example, the solder used contains more than the maximum permissible level of lead, the whole appliance may no longer legally be sold. Non-compliant components and printed circuit boards may, however, be used after 1 July 2006 as spare parts for, or for repairing appliances which were sold before the critical date. Lead-containing solders may also be used in servers and storage systems until 2010, as well as in various types of telecommunication equipment. There is also a comprehensive exemption for military equipment.

The regulations are principally aimed at the manufacturers of electrical and electronic devices, but inevitably all parties in the chain of production and sale are affected to some extent. New lead-free components and manufacturing processes must be made available. Those responsible for development and manufacture will have new challenges in coping with the regulations. End users, on the other hand, will see little change. Building a circuit or device purely for your own use does not constitute bringing it 'onto the market' and so in this case old components and lead-containing solders can still be used.

Purchase and design

The RoHS directive has a double effect on the choice of components, since assembly houses and manufacturers may no longer use lead-containing solders, which have a particularly low melting point (183 °C). This means that, in general, higher soldering temperatures are necessary. Unfortunately it is not possible to deduce from the fact that a component is declared as 'RoHS compliant' that it can withstand higher soldering temperatures! RoHS compliance means only that, for example, the coating on the leads of a component is lead-free tin. Critical components include, for example, electrolytic capacitors, devices in BGA (ball grid array) packages, and SMD connectors. Caution should be exercised when purchasing new versions of components. More on this problem can be found on distributors' websites [4][5][6] (see **Figure 1**).

In a mass production environment a complete changeover for all component types in a single step is thought to be the best way to proceed. This of course demands considerable research into new components, redesigns and experimentation with soldering processes. In this regard it is possible to learn from the experiences of others through the formation of industrial associations and groups. The ZVEI (Central Association of the German Electrical and Electronic Engineering Industry) has published a guide to lead-free soldering, available on the Internet as a free download [7].



Figure 1.
Many component distributors have set up special RoHS pages.

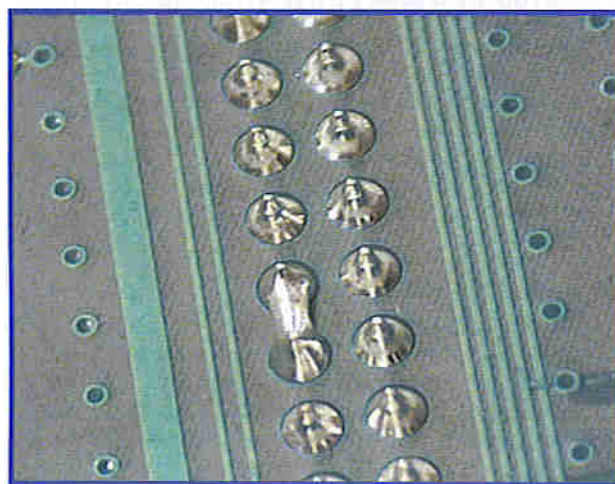


Figure 2.
The formation of solder bridges can be avoided by the use of an inert atmosphere.



Figure 3.
The porous appearance of the surface of a lead-free soldered joint may seem odd at first.

In general significant changes to printed circuit board layout, such as increasing the size of solder pads and increasing the distances between copper areas, are not required. Larger components and larger tracks must however be provided with thermal pads for optimal soldering.

Wave soldering

In industry through-hole (TH) components are most frequently soldered using a wave soldering process. Here the printed circuit board is passed over a solder bath in which a wave is created using nozzles. If it is not desired to completely replace soldering equipment in the switchover to a lead-free process, modifications will be required to existing equipment. The reservoir and pump systems in new equipment are already supplied with surfaces coated so that they are capable of withstanding the more aggressive lead-free alloys; older equipment must be likewise modified.

When lead is substituted by other metals with a higher melting point, the soldering temperature must increase. Whereas until now temperatures of around 230 °C have been adequate, solder baths must now run at temperatures of up to 260 °C. In general the preheat temperature now plays a more important role: large components, with their higher heat capacity, must be checked and adequately heated in order to avoid failure or damage.

There is a plethora of solder alloys available on the market. In general a SnAgCu (tin-silver-copper) alloy, with a melting point of 217 °C, is the most popular and there is already plenty of experience with it. It avoids problems such as whisker formation which can occur with pure tin alloys. These whiskers are threads of solder forming from the soldered points which can unfortunately cause unwanted short circuits.

When using lead-free alloys the contents of the solder bath must be continuously monitored by taking samples, since there is a tendency for the proportion of copper to increase. When this reaches a critical level the solder can flow too readily, leading to unsatisfactory results. Depending to the results of the tests, it is possible to add tin-silver alloy, pure tin, or tin-silver-copper alloy to the solder in the bath.

Reflow soldering

As in the case of wave soldering, reflow ovens (see box) also require modification or replacement by new equipment. The modifications generally include a powerful heater system and improved thermal insulation, in accordance with the higher temperatures involved in the process. Solder bridges must be watched out for: these arise from increased oxidation of the solder and can be prevented by the use of an inert atmosphere (see Figure 2). In mass production the use of an inert atmosphere is essential.

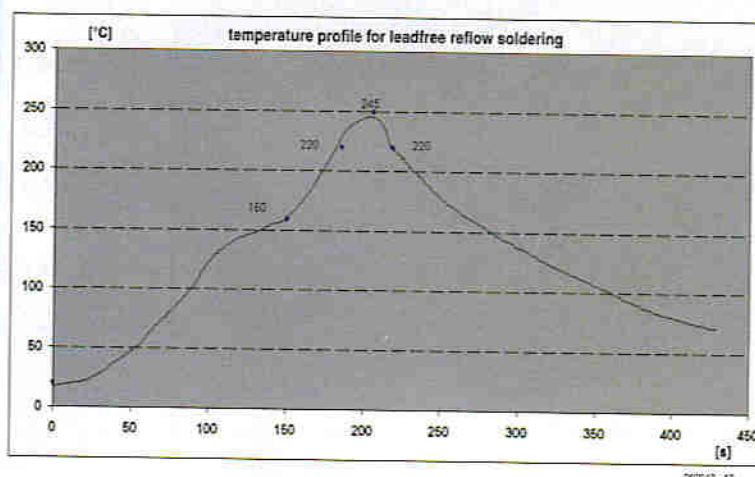
The established manufacturers offer a selection of lead-free solder pastes. When experimenting it is possible to use a standard lead-free solder temperature profile, which will, as a rule, give good results for 90 % of components. The number of available temperature profiles can be rather large, depending to a significant extent on the product range.

Reflow soldering

Although most 'normal' SMD components can still be soldered manually using a fine soldering iron bit and fine solder, components in BGA, CSP (chip scale package) and similar packages can still only be soldered by machine. The so-called reflow process is a reliable method. In this process a solder paste is spread onto the pads on the printed circuit board where the component will sit: the paste can of course be lead-free. The components are then placed on the printed circuit board so that their connections are embedded into the paste. The connections can now be soldered in a reflow oven. This process takes place in five precisely-controlled steps, called 'phases' (phase 1 to phase 5 in the figure above).

Phase 1 is called the 'preheat phase'. The temperature in the reflow oven is gradually increased to approximately 125 °C. The temperature must rise slowly, as otherwise bubbles can form in the solder paste. Phase 2 is the 'soak phase', or 'activation phase'. Here the temperature is very slowly increased to approximately 175 °C. During this phase the solder paste is activated; the flux changes into its liquid state and flows over the pads.

Once the circuit board and components are 'soaked', phase 3, the 'reflow phase', is entered. The temperature rises relatively quickly to above the melting point of the tin in the paste so that it melts, and the actual soldering takes place. With lead-containing solders the target temperature is about 220 °C to 240 °C; with lead-free solders it must be increased to between 250 °C and 260 °C. In phase 4, the so-called 'dwell phase', the soldering temperature is held constant for a few seconds. The tin particles held within the solder paste melt into one another and displace the other components of the paste. Between the component connections and the pads on the printed circuit board there is now only molten tin, which binds them together. After 15 s to 20 s of dwell, phase 5, the 'cooling phase', is entered and the populated board is gradually cooled to room temperature.



Hand soldering

For repairs and hand soldering the switchover will be straightforward: simply turn up the temperature on the soldering station. Lead-free solders corrode the bit more rapidly, although service companies have reported no significant increase in their use of soldering iron bits. Nevertheless, some manufacturers have brought out new products, such as soldering iron bits made of silver to improve heat conduction. In some cases, such as when a circuit board conducts heat away too rapidly, it is possible to obtain better results by providing additional heating using hot air.

Lead-free soldering takes a little getting used to. The joints are not as bright as those made using lead-containing solder and have a porous surface appearance (Figure 3). Lacking lead, the joints are thicker and harder and have a different shape (Figure 4). A joint that has what would have been an unsatisfactory appearance is thus likely to be perfectly good. This calls for new guidelines for the quality control of soldered joints, as laid down in the paper 'IPC A-610D' by the IPC (formerly the Institute of Interconnecting and Packaging Electronic Circuits) [8].

Outlook

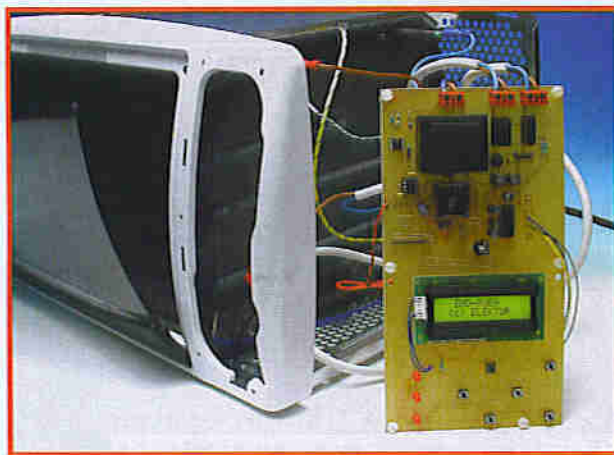
In the medium term the need for two sets of component stores and two sets of soldering stations will disappear.

Niche companies will be set up alongside existing in-house manufacturers and electronics servicing companies, offering repair facilities as well as materials and manufacturing capacity for appliances falling outside the regulations.

For hobbyists the switchover to a lead-free regime means access to a wide range of new solders, fluxes and components. At the same time a wide range of lead-containing materials will disappear from the market. It is



Figure 4. Because of the lack of lead, the shape of the joint is different.



The Elektor Electronics SMD Reflow Soldering Oven

Here at the Elektor Electronics laboratories theory and practice go hand in hand. When we had to solder an FPGA in a BGA package [9], we realised that we needed a reflow oven. Rather than ordering an expensive device, the Elektor Electronics designers had a clever idea: convert their beloved pizza oven into a reflow oven. The team developed a temperature controller circuit based around an AT89C52 microcontroller. Of course, we did not keep the idea a secret

from our readers [10]: the 'SMD Reflow Soldering Oven' project by Paul Goossens, published in the January 2006 issue, generated enormous interest, as evinced by the dozens of reader letters and e-mails we received. There were many questions about reflow soldering and about our oven design in particular, and many interesting modifications were proposed. One UK reader has even converted his toaster into an SMD soldering oven [11]!

It is easy to alter the temperature profile in the controller to suit lead-free soldering using the 'EDIT' function in the microcontroller program: a good starting point is the set of values given in the box 'Reflow soldering', but this is no substitute for a careful study of device datasheets.

expected, however, that in the short to medium term availability of lead-containing components will remain good, since residual stock will come on to the market.

About the author: Felix Meckmann is marketing manager at Schlafhorst Electronics GmbH. The focus of operations for this firm, based in Germany, is the contract development and manufacture of electronic modules, products

and systems. With 130 staff, the company has been making a positive commitment to lead-free technologies since the beginning of 2004. As well as an SMT production line, wave soldering and selective lead-free soldering are available. The company has to date delivered 200,000 RoHS-compliant modules.

(060049)
Felix Meckmann (felix.meckmann@schlafhorst-electronics.de)

Links

- [1] www.europa.eu.int/scadplus/leg/en/lvb/l21210.htm
- [2] http://europa.eu.int/comm/environment/waste/pdf/faq_wEEE.pdf
- [3] Elektor Electronics, January 2006, p. 22 and www.elektor-electronics.co.uk/Default.aspx?tabid=27&year=2006&month=1

- [4] <http://uk.farnell.com/static/en/rohs/>
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- [8] www.leadfree.org
- [9] Elektor Electronics, March 2006, p. 16 and www.elektor-electronics.co.uk/Default.aspx?tabid=27&year=2006&month=3
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- [11] Elektor Electronics online Forum, www.elektor-electronics.co.uk/default.aspx?tabid=29&forumid=16&postid=697&view=topic



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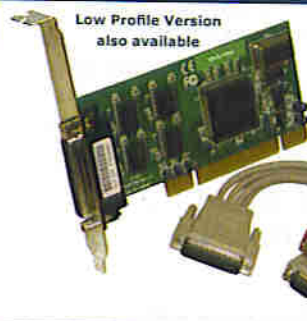
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PCB Production in th

Prototype boards: quick turn-around manufacture,

Ernst Krempelsauer

Once the design of a circuit has reached the point where the PCB CAD data file has been produced, a physical board is usually wanted as soon as possible so that a one-off unit or laboratory prototype can be assembled and tested. In this article we look how to choose between the various alternative routes to manufacture and survey their advantages and disadvantages.

Anyone who has manufactured prototype PCBs themselves, whether using chemical or mechanical processes, will know from experience what the advantages and disadvantages of this route are. It is therefore perhaps worth taking another look at the various options available. In preparing this article we have drawn on our own experiences in the *Elektor Electronics* laboratory and consulted service providers and their customers.

The basics

The basic question to answer is whether one wants to have one's own independent means of producing prototype boards. The simplest route today is surely to out-source the job of manufacturing the circuit board to one of the many service providers.

Tried and tested technologies and free competition in the market ensure that there are in general very few problems with quality or reliability of delivery, and that prices are at an acceptable level. In view of this we would need a good reason to want to make small quantities of printed circuit boards in-house. One clear reason would

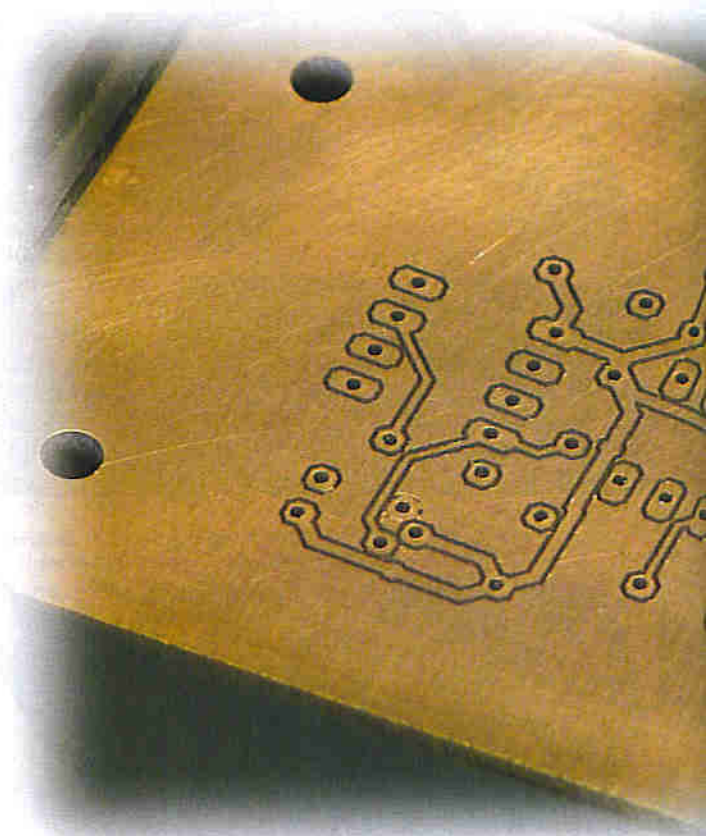
be confidentiality, which would be a consideration in both the military and civilian sectors. But the most important reason would probably be speed. If a design is still showing problems at the second or third version of the prototype, time will inevitably be short. Of course, the shorter the turn-around time requested, the more expen-

"Isolation milling is expensive, slow and technically antiquated."

Dietmar Bungard
(Bungard Elektronik GmbH & Co. KG)

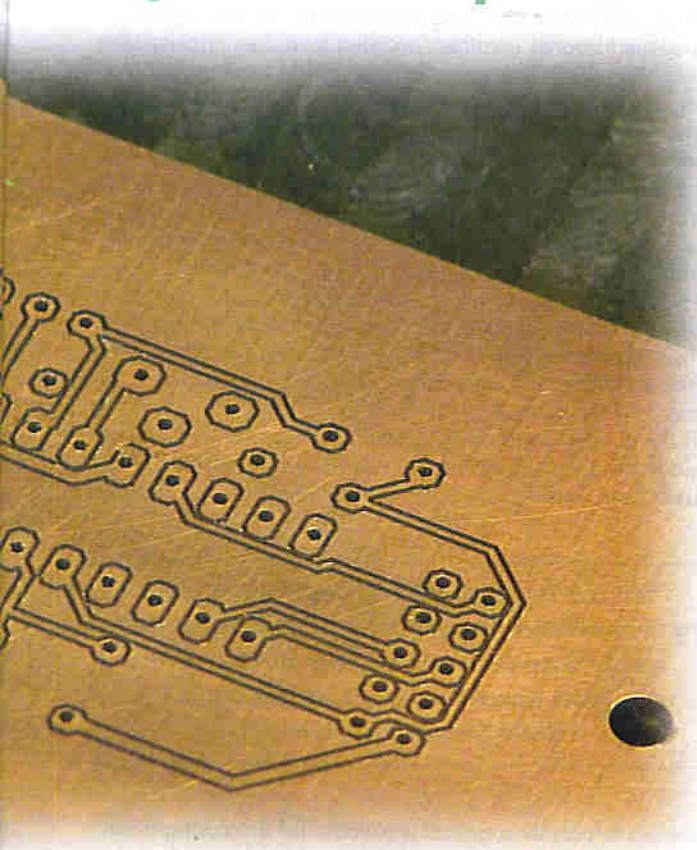
sive contract board manufacture gets.

Further reasons for 'doing-it-yourself' include the benefits of learning the processes involved or even the simple pleasure that can be derived from producing as good a result as possible from the equipment available. This is of less relevance in the professional world: many companies



e Fast Lane

milling, or etch-it-yourself?



Against these advantages there weigh several points that account for the relatively low take-up of the milling method. First is the set-up cost: the cheapest machine, suitable for hobby use, costs around £ 500; the entry-level industrial model from the market leader (LPKF, see p. 34 in the March 2006 issue) starts at around £ 7000. The cost of milling tools, at between £ 5 and £ 10 each, is not to be overlooked. Bungard, for example, specify a life of around 25 m path length for their isolation routing tool. This corresponds to perhaps one densely laid-out Eurocard. Such a complex board might take 20 minutes to mill per side. To this you may have to add the time it takes to convert the layout data into a suitable form for the machine, although most suppliers claim that for their machines this process is not particularly difficult using modern layout programs. Layout programs such as 'Target 3001!' can already work with machine-specific milling tools, and both Target and Eagle support the output of contours and drilling data in the standard HPGL plotter format.

A controversial question, affecting isolation milling as well as other processes, is the production of fine dust particles. Stricter controls on these particles could potentially present a problem.

"For the rapid production of prototypes or small quantities the chemical-free approach, using a milling machine as a plotter, is ideal."

**Kian Kazemzadeh
(LPKF Laser & Electronics AG)**

There are essential differences between a prototype board made using a milling process and one mass-produced using an etching process. This can in particular result in different high-frequency characteristics arising from the differing shape of the track edges. Another difference which it is also essential to be aware of is the poorer solderability of milled boards.

Milling a double-sided board obviously requires two separate operations, doubling the milling time. Stable mounting and careful alignment when turning the board over are essential. Through-hole contacts must be made in a separate process when milling is complete. The mechanical approach of inserting small plugs followed by chemical processing is popular. LPKF also offers a 'semi-chemical' method where a conductive paste is applied through a stencil. The board is then placed on a vacuum table and the paste is sucked into the holes. The paste is heated in an oven and the paste forms a conductive layer on the walls of the holes, making the through-hole contacts. LPKF also offers complete systems for manufacturing multi-layer boards using milling techniques, which is a rather complex process when compared to etching methods.

Small and large

The most economical starting point is the Proxxon MF70 CNC XXL milling machine (**Figure 1**) from Usovo. This is a modified Proxxon MF70; if you already have such a machine, the kit of extra parts is also available separately. In contrast to the more usual 'gantry-style' milling

have gone out of business in the unending quest for such perfection!

If the choice is made to take the do-it-yourself route for one of the above reasons, the next decision is to select between etching and milling. Milling of printed circuit boards is the less widely used procedure (and not just among readers of *Elektor Electronics*), but the impression one receives from the stream of news about the subject is that there is a great deal of interest at least in finding out more about the method. The impression is reinforced by the presence of PCB milling machines at exhibitions. We will therefore start with a look at this method.

Run of the mill

Let's start with a couple of facts. One definite advantage of milling is the speed with which results can be obtained and the fact that the machines are also capable of drilling. A combined drilling and milling machine may also find other applications. And of course, the production of the circuit board in its final physical form takes place without the use of chemistry.

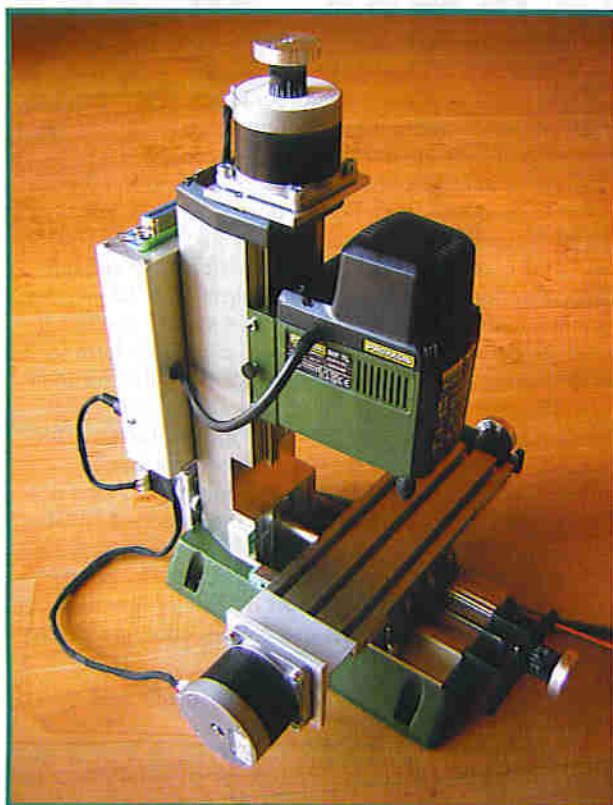


Figure 1.
A modified Proxxon MF70 is, at around £ 500, the cheapest CNC machine available for milling printed circuit boards. (Source: Usovo)

machines used for PCB work, this unit has a fixed milling head and a two-axis table which moves the workpiece under the mill. The travel of the table is 162 mm (in the X axis) by 84 mm (in the Y axis), allowing only half-Euro-card size boards to be milled. For full Eurocard format the MF70 CNC Euro version is needed (for an extra £ 100 or so). Z-axis travel is 88 mm, which explains why the machine is so popular with model builders, for whom using the machine for milling the occasional circuit board might be considered something of a bonus. Peter Urban of USOVO says that using the machine for milling double-sided boards is rather 'ambitious', but emphasises the machine's high stability when compared to simple gantry-style machines, which results in a high level of accuracy. The machine takes around an hour to mill a complicated single-sided Eurocard.

The most economical gantry-style machines are available from StepWalk (Dr Gert Müller) and from Haase. Prices start at around £ 1400, rising rapidly depending on the model and choice of accessories (such as drive motors). The more expensive high-speed spindles (up to 50000 rpm) allow a considerably higher milling speed than the slower 230 V or DC motors. These machines are also capable of a wide range of additional tasks in addition to isolation milling.

The machines made by LPKF, on the other hand, are specially designed for printed circuit board prototyping. **Figure 2** shows the basic model, the ProtoMat S42, which



Figure 2.
Prices for the entry-level model from LPKF start at around £ 7000. (Source: LPKF)

"To me it seems that these days do-it-yourself etching is just something to help explain to non-specialists how printed circuit boards are manufactured."

Dirk Stans (Eurocircuits)

the manufacturer suggests is suitable for engraving front panels and for manufacturing circuit boards with feature sizes down to 100 µm. The spindle rotates at 50000 rpm, allowing a milling speed of 50 mm/s.

Traditional methods

For mass production of printed circuit boards the only reasonable approach is etching. It is also the first choice in many cases for prototype development in the laboratory. Start-up costs are relatively low and, because of the size of the market, there are products from various manufacturers to help with all stages of the process, including solder masks, component overlay printing, and multilayer board production. The differences between the one-off prototype and the mass-produced version are, depending on the system, less than when milling is used, and the disposal of the used chemicals is clearly regulated and relatively straightforward. As in the case of milling, setting up the equipment is only worthwhile if regular use is anticipated, or if contracting-out is for some reason not feasible. The laboratory space required and logistical problems are somewhat greater than in the case of milling and, to do the job properly, up-to-date equipment and a certain amount of discipline are required.

When it comes to speed, the question is debatable. With good equipment and efficient practices etching should be faster than milling, at least for double-sided Eurocards.

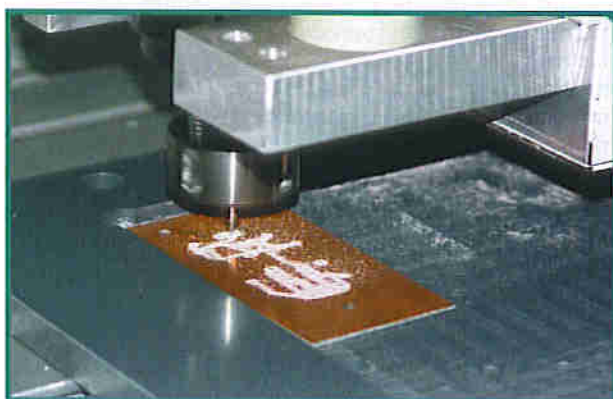


Figure 3.
A PCB milling machine in action. (Source: Charlyrobot)

For special situations such as schools and private users there are low-cost solutions which allow good results to be achieved with reasonable effort. As is so often the case, good tools pay for themselves and cheap equipment is frequently false economy.

Quick service

Turn-around time, the range of services available, and price are the main differentiating factors between prototype PCB manufacturers. If you want a full range of services and the quickest turn-around, the price will be correspondingly high, and perhaps relatively few of the manufacturers will be able to meet your requirements. On the other hand, if you are happy to wait a little longer, and to deal entirely via a website, lower prices are available without necessarily compromising quality. Delivery times can range from a minimum of four hours (for example the 'Superblitz' service available from Contag) to as long as three weeks (for example the 'Plot&Go' service for private individuals offered by ThePCBShop).

By using the 'pool' model to reduce set-up costs (by collecting together individual orders to make for more efficient processing), and the 'on-line' mode to reduce order processing costs, the price for one-off boards can be considerably reduced. As a result ordering prototype boards through well-known suppliers such as Beta Layout/PCB Pool or Elektor's business partner 'The PCBShop' (Eurocircuits) has become the norm, while do-it-yourself produc-

"Do-it-yourself printed circuit board manufacture is particularly suitable for the smaller laboratory if a quick development cycle is needed."
Jochen Lutz (Radix GmbH)

tion has become less popular. There are of course differences in price and levels of service, which can become particularly relevant if you have special technical requirements or strict deadlines. On the customer side considerations include not just the reliability and quality of the supplier but also the time involved in placing the order. The board manufacturers and the layout program suppliers have cooperated to solve this problem so that it is possible, for example, to order the circuit board online directly from the layout program. The websites of layout programs such as Eagle, Target and Abacom/Sprint Layout describe the procedure and have links to circuit board manufacturers.

Conclusion

The quick turn-around printed circuit board manufacturers now offer good quality and value for money, and are in many cases the first choice. Nevertheless, in many cases one will not wish to dispense entirely with the facility to make one's own boards. That is the current situation in the *Elektor Electronics* laboratories: whereas right up the 1990s we made practically all our prototypes for printed circuit boards ourselves, including double-sided boards and those with a component overlay, we now generally order prototypes from one of the online PCB manufacturers. Contrary to what some older readers believe we never undertook mass-production of our boards our-

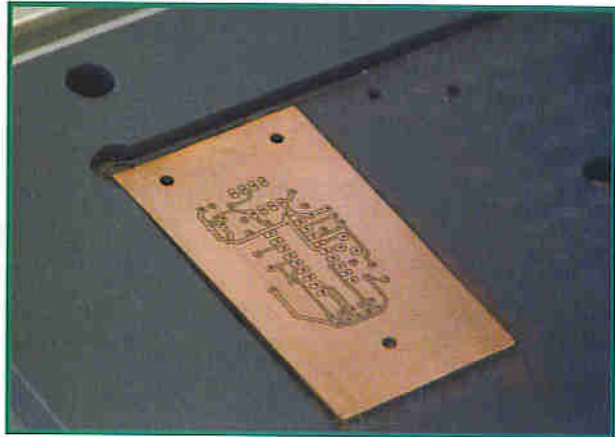


Figure 4.
Typical single-sided printed circuit board made by milling.
(Source: Charlyrobot)

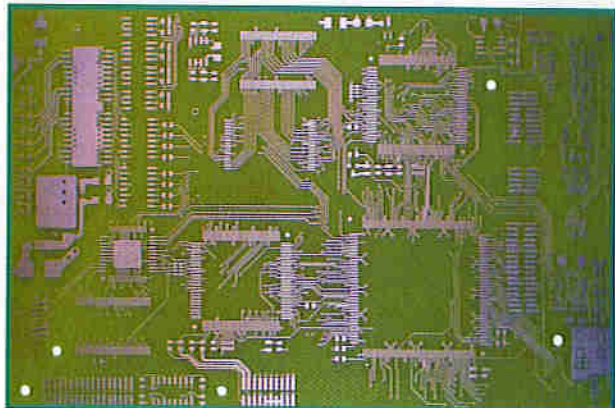


Figure 5.
This milled printed circuit board is somewhat more complicated.
(Source: LPKF)

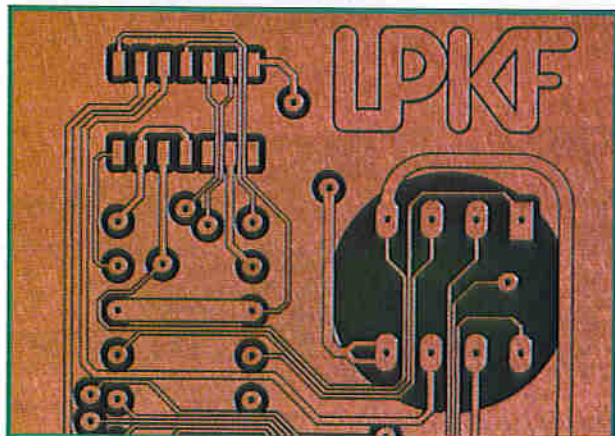


Figure 6.
Four-layer printed circuit board with 100 µm features made by milling.
(Source: LPKF)

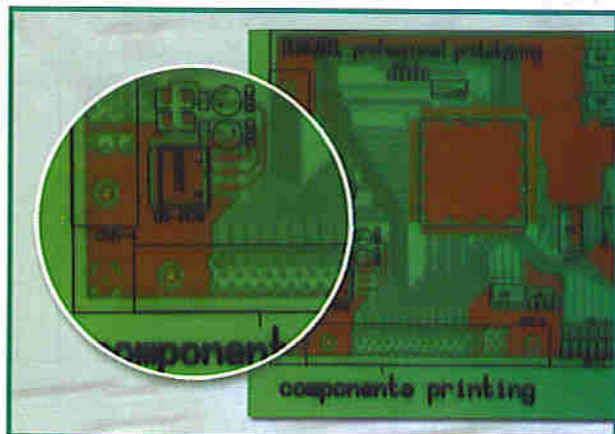


Figure 7.
A component overlay can easily be added to prototype printed circuit boards.

selves. As befits an international magazine with several editions covering Europe, we use several suppliers, which between them have a presence throughout Europe and beyond.

Our in-house PCB etching and drilling facilities serve as a backup for difficult and urgent cases only, and (much appreciated by the electronics enthusiast whose day job is at *Elektor Electronics*) as an economical and quick solution for single-sided boards.

Milling printed circuit boards is reserved for special situations. For example, a model builder who already owns a suitable milling machine might also use it for making

printed circuit boards. Regarding another scenario, Markus Friedrich of Friedrich Design Bureau (a supplier of Target) says: "in our experience we see mainly schools

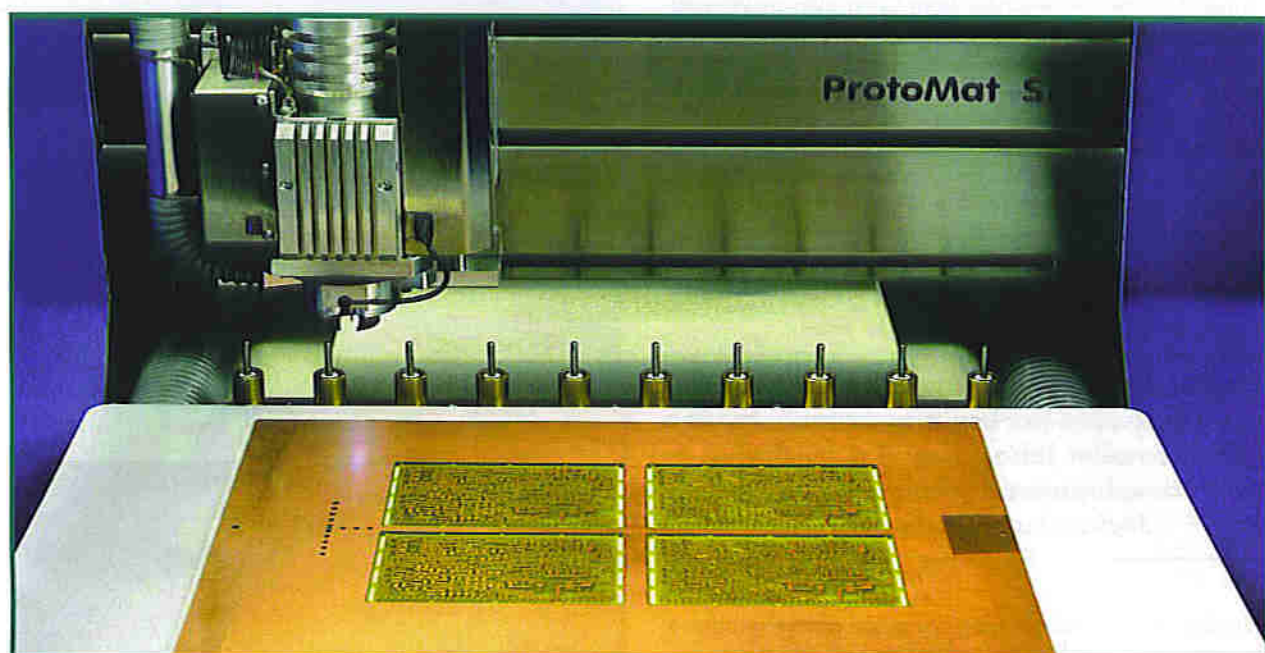
and universities that want simultaneously to teach layout techniques using CAD systems and how to use CNC milling machines".

For industrial users LPKF seems to be the only supplier of a complete system for manufacturing printed circuit boards with special requirements using milling

"Single-sided SMD is ideal for do-it-yourself etching. Quick turn-around contract service is the only realistic method for double-sided prototypes."
Kurt Harders (Elektor Electronics reader)

technology, but the capital costs involved are comparatively high.

(060051-1)



The following have contributed comments and information to this article:

Dietmar and Jürgen Bungard
 (Bungard Elektronik GmbH & Co. KG)
 Markus Friedrich (Ing.-Büro Friedrich)
 René Drescher (Contag GmbH)
 Kurt Harders
 Claudio Hediger
 Kian Kazemzadeh (LPKF Laser & Electronics AG)
 Burkhard Lewetz
 Jochen Lutz (Radix GmbH)
 Dirk Stans (Eurocircuits BVBA)
 Peter Urban (Usovo)

Further reading

Making your own PCBs,
 Elektor Electronics, September 2002, p. 40
 (downloadable).
 Printed Circuit Board Production,

Elektor Electronics, November 1994.

Links

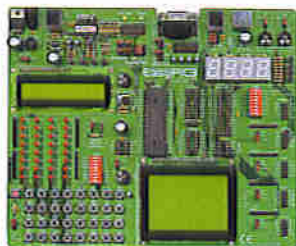
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www.usovo.de (Proxxon MF70 CNC XXL, in German only)
www.lpkf.com/home.htm (LPKF ProtoMat S42)
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- On-board LEDs, switches, two RS-232 interfaces, RS-485 interface, two CAN interfaces, real-time clock, 12-bit A/D and D/A, and CF card slot
- All I/O lines available for expansion
- dsPICPRO Starter Pack includes:
 - ✓ dsPIC30F6014 DSC module
 - ✓ 16x2 character LCD
 - ✓ 128x64 pixel graphic LCD
 - ✓ DS18S20 temperature sensor
 - ✓ USB programming/power lead
 - ✓ Programming software and examples

AVR

EasyAVR3 AVR Starter Pack £99.00



- High quality development board
- Built-in USB 2.0 programmer
- Windows 98/ME/2000/XP compatible
- Supports 8, 20, 28 and 40-pin DIP AVR microcontrollers
- On-board LEDs, switches, potentiometer, RS-232 interface, 12-bit A/D and D/A, and MMC/SD card slot
- All I/O lines available for expansion
- EasyAVR3 Starter Pack includes:
 - ✓ ATmega8535 microcontroller
 - ✓ 16x2 character LCD
 - ✓ 128x64 pixel graphic LCD
 - ✓ DS18S20 temperature sensor
 - ✓ USB programming/power lead
 - ✓ Programming software and examples

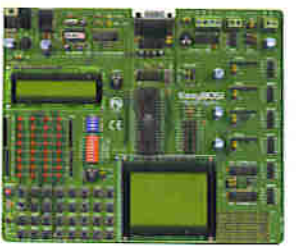
BIGAVR 64-pin AVR Starter Pack £119.00



- High quality development board
- Built-in USB 2.0 programmer
- Windows 98/ME/2000/XP compatible
- Supports 64-pin AVR microcontrollers
- On-board LEDs, switches, potentiometers, two RS-232 interfaces, PS/2 connector, and MMC/SD and Compact Flash card slots
- All I/O lines available for expansion
- BIGAVR Starter Pack includes:
 - ✓ ATmega128 MCU module
 - ✓ 16x2 character LCD
 - ✓ 128x64 pixel graphic LCD
 - ✓ DS18S20 temperature sensor
 - ✓ USB programming/power lead
 - ✓ Programming software and examples

8051

Easy8051 8051 Starter Pack £99.00



- High quality development board
- Built-in USB 2.0 programmer
- Windows 98/ME/2000/XP compatible
- Supports 20 and 40-pin DIP Atmel 8051 Flash microcontrollers
- On-board LEDs, switches, potentiometer, RS-232 interface, 12-bit A/D and D/A, and two additional 8-bit I/O ports
- All I/O lines available for expansion
- Easy8051 Starter Pack includes:
 - ✓ 40-pin 8051 microcontroller
 - ✓ 16x2 character LCD
 - ✓ 128x64 pixel graphic LCD
 - ✓ DS18S20 temperature sensor
 - ✓ USB programming/power lead
 - ✓ Programming software and examples

PSoC

EasyPSoC3 PSoC Starter Pack £119.00



- High quality development board
- Built-in USB 2.0 programmer
- Windows 98/ME/2000/XP compatible
- Supports 8, 20, 28 and 48-pin DIP PSoC mixed-signal controllers
- On-board LEDs, switches, potentiometers, RS-232 interface, RS-485 interface, CAN interface, real-time clock, and MMC/SD and CF card slots
- All I/O lines available for expansion
- EasyPSoC3 Starter Pack includes:
 - ✓ 48-pin PSoC microcontroller
 - ✓ 16x2 character LCD
 - ✓ 128x64 pixel graphic LCD
 - ✓ DS18S20 temperature sensor
 - ✓ USB programming/power lead
 - ✓ Programming software and examples

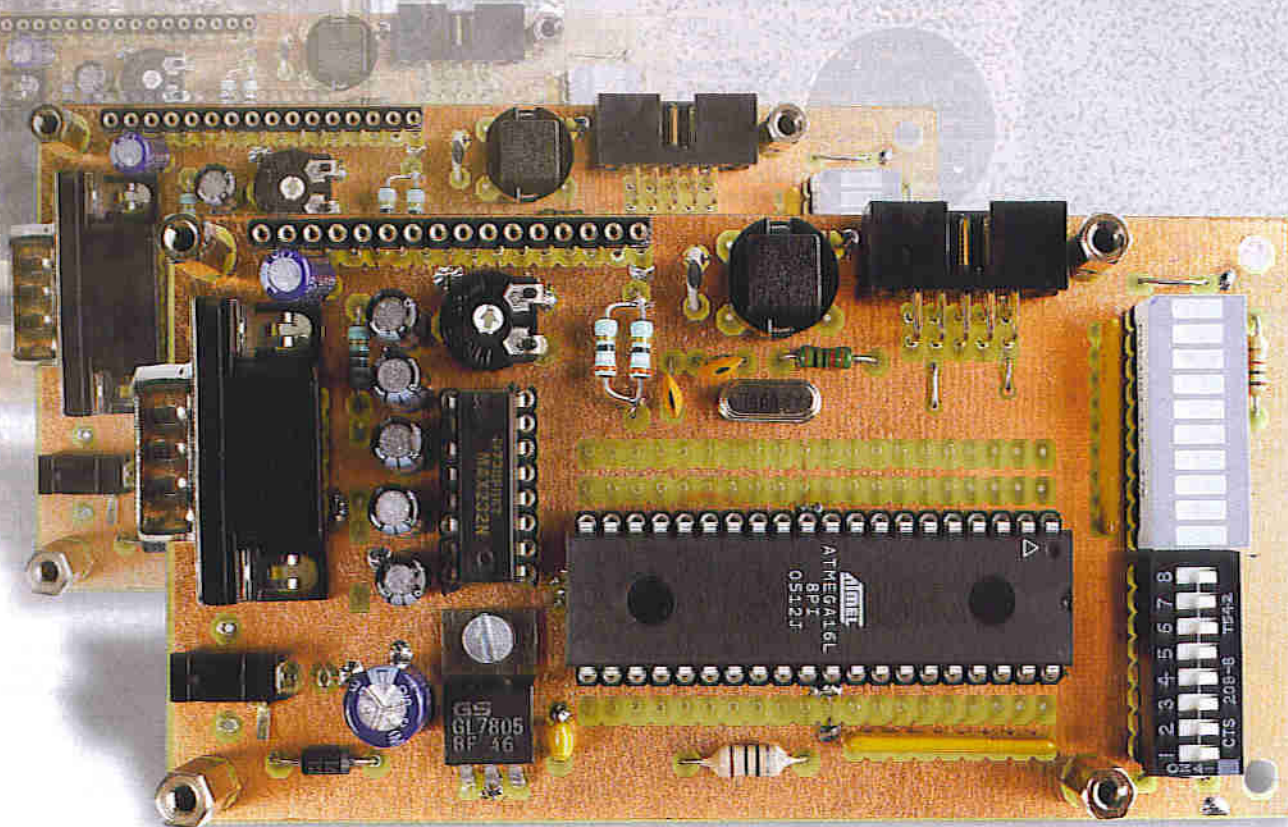


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Mini ATmega Board



Florian Schäffer

It's about time, you might say! After all, even if the ATmega microcontroller isn't necessarily mega, it's still quite popular and we feel it hasn't really received the attention it deserves in *Elektor Electronics*. The Mini ATmega Board described here puts a change to that, and a nice application for it — our Standalone OBD2 Analyser—is featured in an accompanying article.

The Mini ATmega Board is a complete application board for the ATmega16 and ATmega32 members of the Atmel AVR family. It includes an LCD port, a serial interface, and abundant I/O lines. For programming, the board also has a mini-interface for communicating with a PC serial port.

There are numerous potential applications for small single-board comput-

ers in the domestic and hobby realm, such as central heating controllers, roller-shutter controllers and alarm systems. Another popular application is controlling autonomous robotic systems. In any case, developing your own application programs requires a certain amount of programming expertise, and this board with its programming interface is naturally quite

suitable for acquiring that expertise. It's easy to convert user inputs into actions and responses, even with only a small program.

Simple but versatile

In its standard configuration, the board is intended to be fitted with an ATmega16. This relatively inexpensive

For ATmega16 and ATmega32

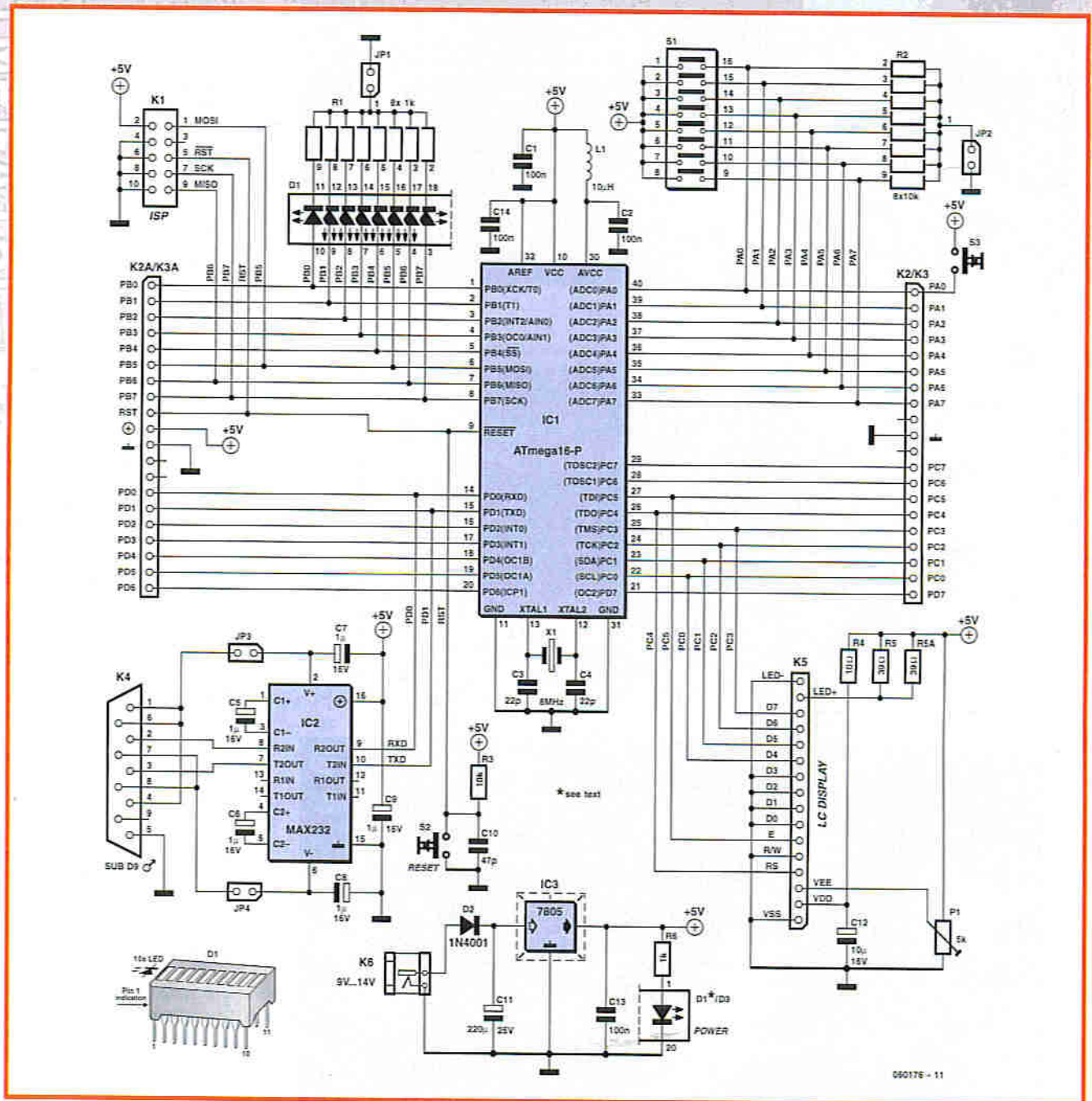


Figure 1. Schematic diagram of the Mini ATmega Board, which forms a good basis for compact applications.

microcontroller from the 8-bit AVR RISC family is quite suitable for beginners due to its DIL package, which is easier to handle than the SMD packages of the smaller AVR microcontrollers. The ATmega8, which comes in a skinny 28-pin package but still has a large number of I/O pins, is also very popular. However, its 8 KB of internal flash program memory is a bit on the

skimpy side, so we prefer the larger ATmega16 with twice as much memory. If you need even more memory, the pin-compatible ATmega32 can also be fitted to the board. As the latter device is also largely software-compatible, it's generally only necessary to recompile the software in question without having to make any other modifications.

Another reason for the popularity of the ATmega processors is the fact that many major elements are already integrated. In addition, the 32 I/O lines of the two larger versions provide adequate connectivity for supplementary hardware, including eight pins that can be routed to an internal analogue-to-digital converter. The processor can run at a

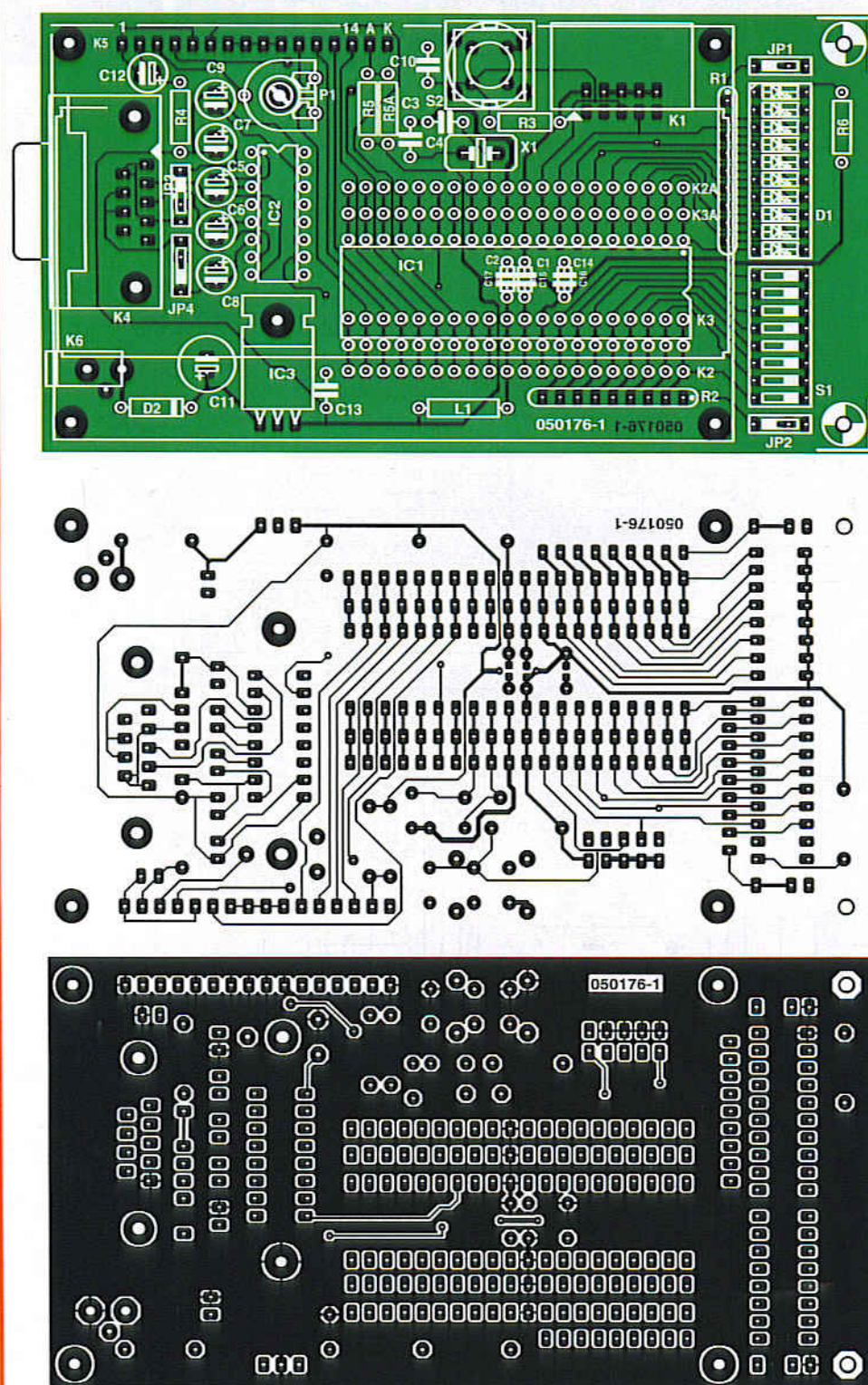


Figure 2. Track and component layouts of the circuit board.

COMPONENTS LIST

Resistors

- R1 = SIL array 8 x 1k Ω
- R2 = SIL array 8 x 10k Ω
- R3 = 10k Ω
- R4 = 10 Ω
- R5, R5A = 39 Ω
- R6 = 1k Ω
- P1 = 10k Ω preset

Capacitors

- C1, C2, C13, C14 = 100nF ceramic
- C3, C4 = 22pF
- C5-C9 = 1 μ F 16V radial
- C10 = 47pF
- C11 = 220 μ F 25V radial
- C12 = 10 μ F 16V radial

Semiconductors

- D1 = LED-Array with 10 LEDs
- D2 = 1N4001
- D3 = contained in D1
- IC1 = ATmega 16-PC (DIP40 case)
- IC2 = MAX232 (DIP16 case)
- IC3 = 7805 (TO220 case)

Miscellaneous

- JP1-JP4 = wire link, microswitch or 2-way pinheader with jumper
- K1 = 10-way boxheader
- K2, K2A = 20-way SIL pinheader
- K3, K3A = optionally fitted
- K4 = 9-way sub-D plug (male), PCB mount
- K5 = 16-way SIL socket, (e.g. cut off from a 40-way wirewrap socket) and mating SIL plug
- K6 = mains adaptor DC socket, PCB mount
- IC socket, 1 x 40 way, 1 x 20 way, 1 x 16 way
- S1 = 8-way DIP switch
- S2 = pushbutton, 1 make contact (e.g. Conrad Electronics # 700665)
- L1 = 10 μ H (fixed inductor)
- X1 = 8MHz quartz crystal
- Enclosure, Hammond type 1591-D blue *
- 16-way flatcable (a few centimetres)
- PCB, order code **050176-1**, supplied including programming adapter board **050176-2**.
- * not required in combination with OBD2

maximum clock rate of 16 MHz, which yields respectable computing power. Processing complex, time-critical tasks is usually not a problem, because most of the machine instructions require only two system clocks

for execution. Additional useful features include internal software UARTs for serial communication and the ability to respond to interrupts and handle system crashes using a watchdog timer.

Everything on board

As you can see from the schematic diagram (Figure 1), only a few components are fitted to the board. Of course, operating power and a clock source are

essential. The first is provided by a 5-V voltage regulator (IC3), and an 8-MHz crystal sets the rate of the microcontroller's internal oscillator.

Nearly all of the other components are used to support the various interfaces. K1 is the connector for the programming adapter. The circuit arrangement is compatible with conventional 10-lead adapters, such as those used with the Atmel STK boards.

The RS232 port (K4) can be programmed via the internal software USART, and it can achieve high data transmission rates thanks to interrupt control and buffering. The two jumpers JP3 and JP4 allow +10 V and -10 V to be connected to the D-Sub connector in order to power 'vampire circuits'. A null modem cable must be used to connect the port to a PC, and jumpers JP3 and JP4 should be left open in that case.

A few switches and LEDs are naturally quite welcome for simple experiments using the board. Consequently, a set of LEDs (LED array D1) and DIP switches (S1) are connected to the I/O lines. The ATmega can supply up to 40 mA per pin to drive LEDs or other components directly without additional circuitry. If you want to use the port lines for some other purpose, the pull-down resistors (array R2) and LEDs can be disabled by jumper JP2 or JP1, respectively. If port A is used as an output, the DIP switches must be switched off (open) to avoid damage to the IC.

Components L1, C2 and C14 are provided to improve the accuracy of the A/D converter. If an accurate A/D converter is not needed, these components can be omitted and L1 can be replaced by a wire bridge.

A LCD module with four rows of 20 characters (4 × 20) is the preferred choice for the display and a perfectly suitable type is offered through the Elektor SHOP. The board is laid out to exactly fit such a display module. The display can be connected using a pair of flat cables. However, a more elegant solution is solder half a wire-wrap IC socket to the circuit board. If a pin header is fitted to the LCD board, it can be plugged directly into the socket. As there are many similar versions of this standard type of display, you should check carefully to make sure the pinout matches the board layout. The modern blue versions are of course easier on the eye than the usual green versions, but as so often happens, it costs a bit more to have a special taste.

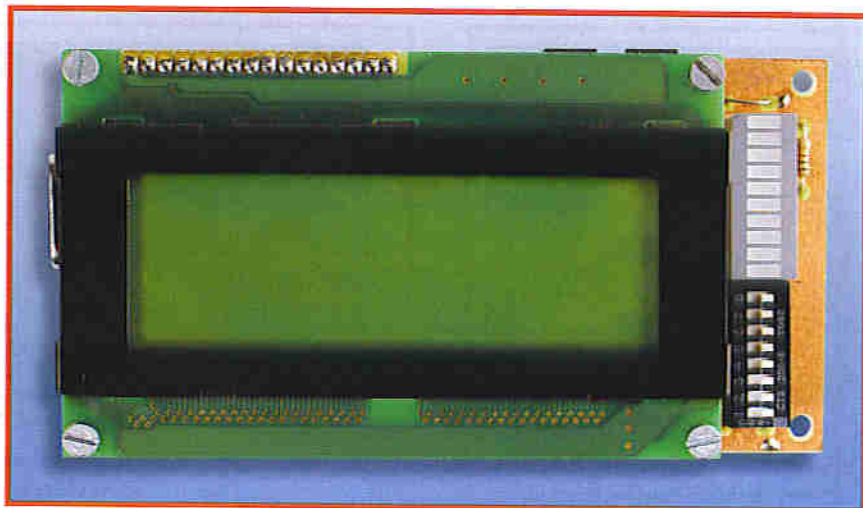
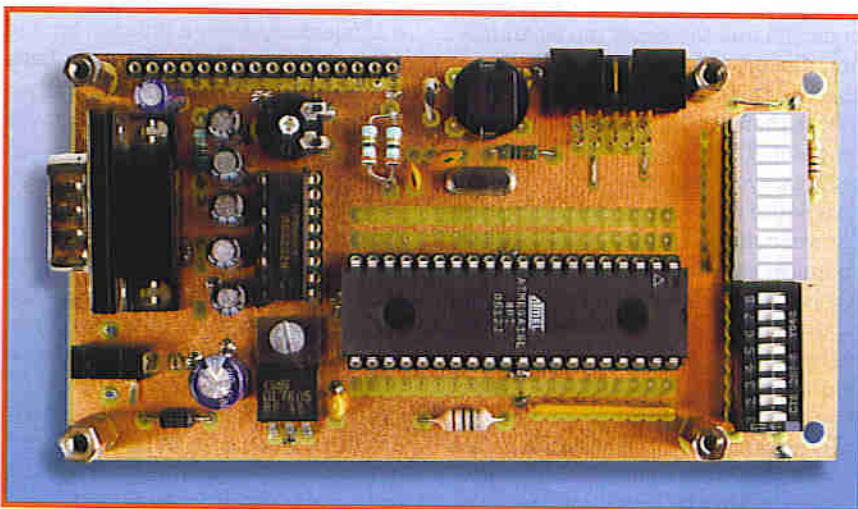


Figure 3. The fully assembled prototype board.



Don't forget to adjust the contrast setting with P1 when you first power up the board – otherwise you might think the display is defective, because you won't see anything if the setting is wrong.

A LED array with ten LEDs is recommended for D1. In that case, D3 is automatically the tenth (uppermost) LED in the array, and the ninth LED is not used. If you can only obtain an array with eight LEDs, fit it in the lower eight positions. The ninth position will then remain open, and a normal LED can be fitted in the tenth position for D3.

K3 and K3A can be used to fit pins on the bottom of the board. That will allow the entire board to be plugged into another board as a replacement for an ATmega for experimental purposes. K2 and K2A are left open for connecting I/O lines.

The only thing left to mention is the decoupling capacitors under the micro-

controller. If you use a socket for the microcontroller, there will probably be enough room on top of the board to fit small capacitors. If that isn't possible, solder three capacitors in SMD-0805 packages to the pads provided for that purpose on the bottom of the board.

Programming

The microcontroller can be programmed directly from a PC via a simple programming adapter (see inset). A variety of small programs are available for this purpose. Although some of them are not especially user-friendly, they all do the job. For instance, you can use PonyProg to download fully compiled programs to the ATmega and set the most important (and crucial) fuse bits.

The fuse bits are used to configure the microcontroller, and this can lead to unfortunate situations in which you lock yourself out, for instance if you

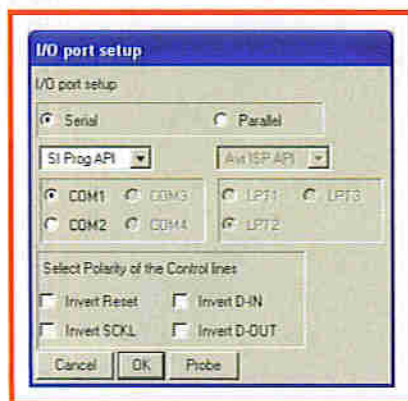


Figure 4. The correct settings must be configured very carefully in PonyProg before the microcontroller is programmed.

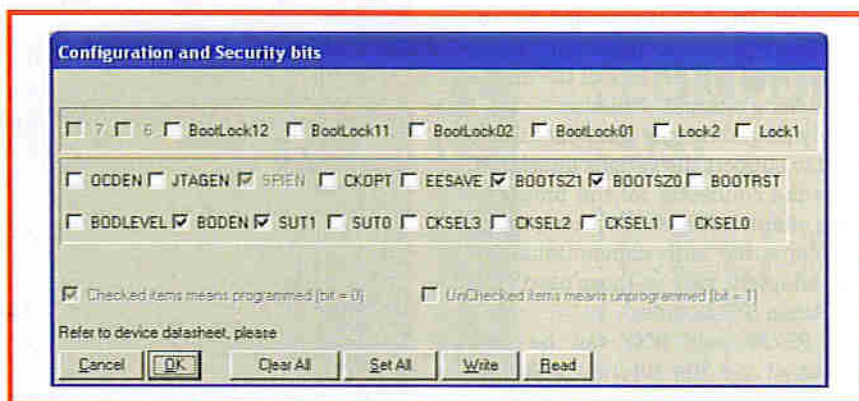


Figure 5. These fuse bits must be set to use an external 8-MHz crystal and enable brownout protection.

configure the clock source incorrectly or reconfigure the Reset pin as an I/O pin. On top of that, the AVR data sheets use a somewhat puzzling logic that is then partially inverted by the program. The first time you use the program, you must use Setup / Interface Setup to configure the right settings and then select the proper microcontroller type in the Devices menu. It's certainly a good idea to use the programmer to read the actual settings of the fuse bits (via Security and Configuration Bits in the Command menu if you're using PonyProg) before you start programming. Not every program does this automatically. You can then compare the bit settings to the descriptions provided in the data sheet. **Figure 4** shows the required settings for using an external 8-MHz crystal and enabling brownout detection, which resets the processor when the supply voltage is applied or removed. Data loss could occur if brownout detection is not used, because no external circuitry is provided for that purpose.

Free development environment

Numerous development environments are available for the AVR family, and it's easy to develop programs in Basic using BASCOM-AVR (free for code sizes up to 4 KB), in assembly language using the free AVR Studio environment, or in GCC using the free WinAVR environment.

The example applications for this board were generated using WinAVR, compiled for the ATmega16, and converted to machine language, so all you have to do is use the programmer to download the resulting hex files to the flash memory of the microcontroller. If

you want to recompile the code to use a different crystal or a different type of ATmega microcontroller, you only have to modify the 'make' file accordingly. The AVR GCC Tutorial referenced the link list provides a very extensive introduction to C programming, although you must always bear in mind that many of the examples were developed for somewhat older types of microcontrollers (now discontinued) and require some changes. The routines for the LCD may also need slight modifications, because even though very good general-purpose templates are already available, they have not been included in the examples in order to keep the code as simple as possible.

All the examples can be downloaded from the *Elektor Electronics* website (www.elektor-electronics.co.uk) in a Zip file. You can use these programs to become familiar with all the essential components and test your board. To get started, you could use the simple 'blinking LEDs' program. The next step would be to display a message on the LED or try out data communications via the serial interface.

As already mentioned in the introduction, an interesting application for this board is described in a companion article in this issue. It is a stand-alone OBD display unit for car diagnostics, which you can also use to display vehicle-specific data 'on board' via the LCD module while you are driving.

Extensions

If you are interested in extending the board after successfully completing your initial programming and application projects, there are many possibilities – far too many to mention them

all in this article. For instance, you could implement an I²C bus with only a few additional components, add a USB port, or even connect an SC memory card to store measurement data for subsequent analysis using a PC. Naturally, you can also make contact with other ATmega fans in the various microcontroller forums, including (of course) the one at www.elektor-electronics.co.uk, and various newsgroups.

(050176-1)

Items available for this project

050176-1 PCB, supplied including programming adapter board (050176-2).

050176-42 Programmed ATMEGA16

050176-72 Kit of parts, includes ATmega board 050176-1, programming adapter board 050176-2, preprogrammed ATmega microcontroller (with OBD2 program), all components for both boards but excluding LC display.

050176-73 LCD, module, 4 x 20 characters, 60 x 98 mm, with background lighting.

050176-74 Case, Bopla Unimas 160 with perspex cover and mounting plate

Available from
www.elektor-electronics.co.uk
Hyperlinks for the project.

050176-11.zip Development software including program examples (free download).

In-system programming

The minimum circuit configuration for an ATmega actually amounts to nothing more than a supply voltage. The external crystal can be omitted if you use the internal oscillator. However, the processor clock rate is not defined especially accurately in that case, so operation using the internal oscillator is only suitable for applications that are not time-critical.

Aside from the supply voltage and the crystal (if used), you also need a programming interface port to load a program into the ATmega. As the ATmega has an in-system programming (ISP) interface, it can be programmed in the application circuit – or reprogrammed as often as desired. The flash memory can handle up to 10,000 write operations, and the EEPROM can handle up to 100,000.

The programming adapter described here can be connected directly to a PC using a one-to-one cable. Connect the other end of the adapter to the ISP connector (K1) of the Mini Mega Board, and you're all set to program the microcontroller directly from your PC.

The circuitry of the programming adapter (**Figure 1**) can be built into the housing of a 9-way D-Sub cable connector to produce a handy programming adapter cable.

Assembling the circuit on the small circuit board (**Figure 2**) is not particularly difficult, but it does require a steady hand and a bit of care. Before fitting the components, check to make sure the board fits in the housing of the D-Sub connector. Then fit the SMD components first, followed by K2 on the other side of the board. Before soldering the D-Sub connector (K1), check again to make sure the board fits. In our prototype, we removed the rear wall of the connector housing. That allowed K2 to just fit, and the flat cable could be fed out without any problem. Do not solder K1 in place until you are sure that the board fits in the connector housing. It will probably be necessary to shorten the pins of K1 slightly and fit the board at a bit of an angle. As the connector housing is made from metal or conductive plastic, you should cover the inside with insulating tape to prevent unwanted contact with the circuit board.

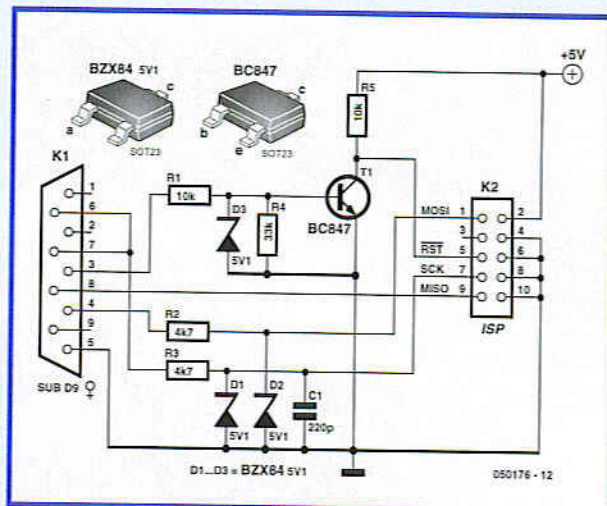


Figure 1. Circuit diagram of the programming adapter.

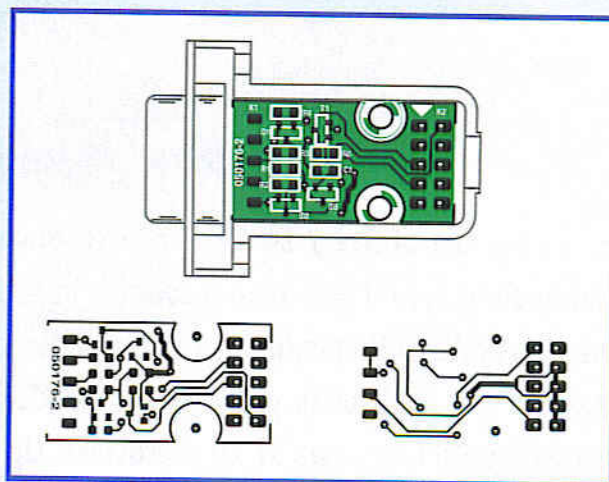


Figure 2. Track side and component side layouts of the programming adapter circuit board.

COMPONENTS LIST

(programming adapter)

Resistors (SMD 0805)

R1, R5 = 10k Ω
R2, R3 = 4k Ω 7
R4 = 33k Ω

Capacitors (SMD 0805)

C1 = 220pF

Semiconductors

D1, D2, D3 = zener diode 5V1, 250 mW, SOT23 case (e.g. BZX84 5V1 SOT23)
T1 = BC847 (SOT23)

Miscellaneous

K1 = 9-way sub-D socket (female) with case
K2 = 10-way pinheader
10-way flatcable (0.5 - 1 m)
10-way UIDC connector for flatcable
PCB, order code **050176-2** (see SHOP pages or website)

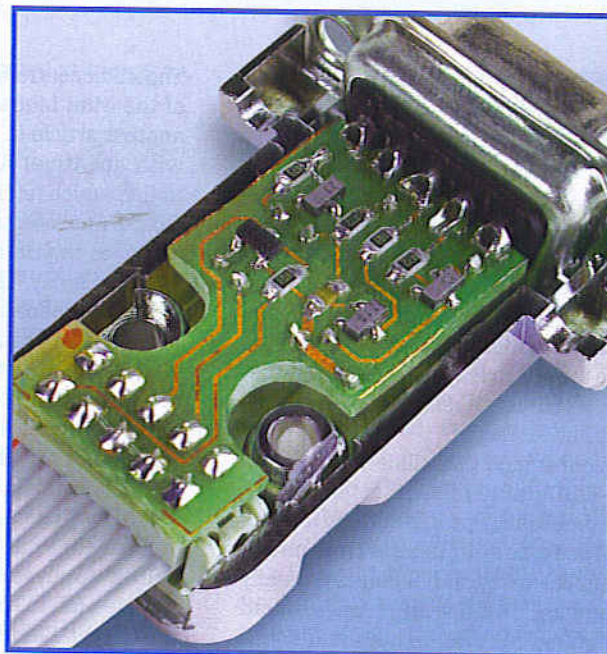


Figure 3. The circuit board with the SMD components fitted.

Onboard OBD-2

Florian Schäffer



You can use the OBD-2 / EOBD diagnostic connector required in all recent cars to read out a lot of interesting data if you have a suitable interface adapter and a notebook computer. An even more practical solution is to use the stand-alone analyser described here, which can be used as a hand-held unit or fitted in your car. Diagnostic data is evaluated using an ATmega16 and shown on an LCD with four rows of 20 characters. Up to eight parameters can be constantly shown on the display while you're driving. Having this information at your fingertips can be especially handy if you have car trouble.

It seemed like an obvious idea: why not use the OBD-2 analyser described in the 2005 Summer Circuits issue more than just twice a year? After all, the car's OBD-2 interface provides interesting data all the time while the vehicle is underway, although using a notebook computer as a display while travelling is rather impractical. Just as with navigation systems, the only suitable approach is to use a portable display or a built-in display with convenient dimensions.

No sooner said than done. Fortunately, the OBD data is not so complex that the processing power of a PC is actually necessary to handle it. A microcontroller with a serial port is perfectly adequate, and an easy-to-read alphanumeric LCD is a lot more suitable than a cumbersome notebook screen for displaying the data in a car.

The microcontroller hardware consists of the Mini Mega Board described in another article in this issue. It is fitted with an Atmel ATmega16 microcontroller, which fetches the data from the OBD-2 analyser via a serial interface, analyses the data, and presents it on the LC display. The board already has all the components necessary for this application, except a pushbutton switch on PA0 for configuring the display parameters.

As the available readings vary from one vehicle to the next, the display should be freely configurable so the digital cockpit can be adapted to every vehicle that can supply data to the OBD-2 Analyser. To find out which vehicles fall in that category, you can consult the *Elektor Electronics* forum or the database referenced in the link list at the end of this article. Thanks to this

configurability, each user can personally decide which of the available readings should be displayed and whether to display the readings in short form or long form.

Combo

As the OBD-2 Analyser and the Mini ATmega Board (Figure 1) both have a full-fledged serial interface, it's easy to establish a communication link between the two boards. With regard to mechanical mating of the two boards to form a stand-alone analyser, refer to the capsule instructions listed in the 'Step by Step' inset.

The boards can be powered from the OBD-II connector. However, the supply voltage on that connector is unswitched, so it's worth having a look at the fuse box to see whether a

Analys

Car diagnostics on the go

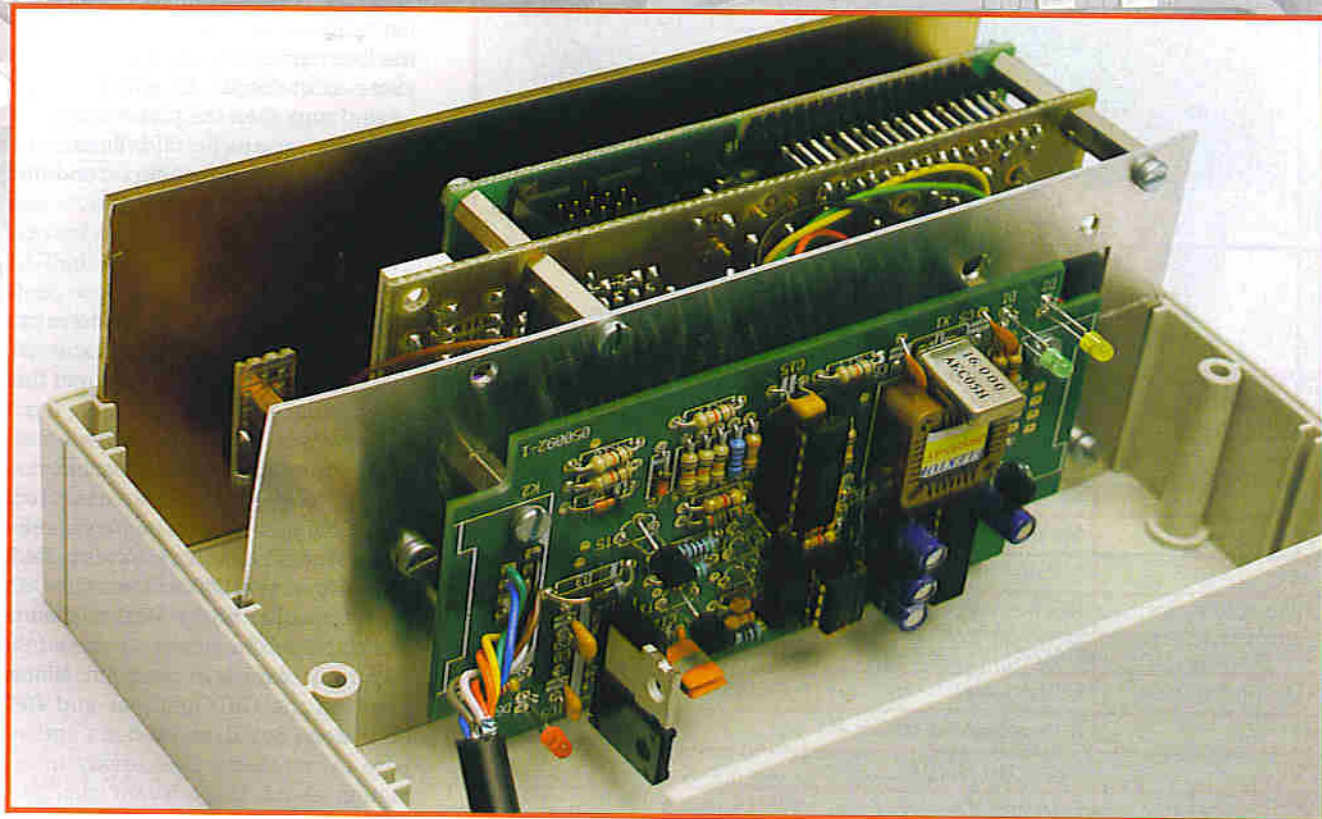


Figure 1. OBD-2 Analyser board and ATmega board after assembly.

'switched ignition plus' terminal is available so the boards will only be powered when the ignition switch is on. That's more practical than pulling the OBD plug or using an additional switch.

One problem that cannot be ignored for in-car use is the large temperature range. Many inexpensive LCD modules are not designed for the freezing temperatures that can occur in cars in the winter. Freezing of the liquid crystal medium can cause permanent damage. Most modules are more tolerant with regard to the upper end of the temperature range. The module shown in components list for the Mini Mega Board has an operating temperature range of -20°C to $+70^{\circ}\text{C}$, and it can withstand temperatures as low as -30°C without damage when not operating. However, the maximum allowable current for the

LED backlight is reduced at temperatures above $+25^{\circ}\text{C}$.

What do you want to see?

Information about the ignition timing advance or exact intake air volume is probably not as interesting in normal driving situations as the engine speed (rpm) or vehicle speed, to mention two examples. It's commonly known that standard speedometers read slightly high despite using electronic drive, with the deviation being as much as 10 km/h depending on the speed. Interestingly enough, a significantly more accurate value is output by the OBD system. Comparative measurements using a stopwatch and a GPS receiver showed that the OBD-II system provides a very accurate indication of the true speed, and the OBD-

controlled digital cockpit display provides an accurate reading over the entire speed range. Of course, if you rely on that reading you will lose the 'margin of safety' that has probably saved you from being caught in a radar trap several times already. If you don't already have a tachometer, or if you mistrust the one fitted in your car, you can also obtain reliable rpm data from the OBD-II system.

The exact coolant temperature is another thing that is doubtless interesting. Unfortunately, there's no uniform specification for the OBD-II interface with regard to outputting the water temperature or the oil temperature. The oil temperature is more commonly output with diesel vehicles than with petrol vehicles, which usually output the water temperature. You can figure out where the sensor is fitted by

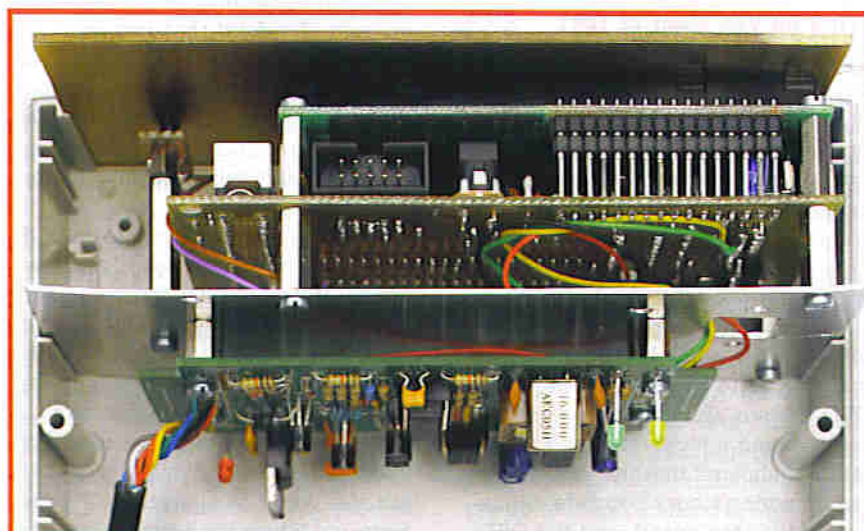


Figure 2. Prototype of the stand-alone OBD analyser.

Table 1. OBD-2 Analyser response to a request to provide the PIDs available in the vehicle.

| Byte | Meaning |
|------|-----------------------------------|
| 06 | Reply ID |
| 02 | Mode 2 response (report readings) |
| 0A | Number of following bytes (10) |
| 48 | Protocol information |
| 6B | Protocol information |
| 10 | ECU address |
| 41 | 40 + requested service (1) |
| 00 | Requested PID (0) |
| 98 | First data byte (MSB) |
| 3F | Second data byte |
| 80 | Third data byte |
| 11 | Fourth data byte (LSB) |
| 6C | Checksum |

Figure 3. Assembly of the boards shown in our prototype.



observing the time behaviour of the temperature reading provided by the OBD system. If the temperature increases linearly after a cold start, it represents the coolant temperature. If instead the indicated value does not increase until the engine has been running for a while, and then increases rapidly to around 90 °C, it comes from an oil-temperature sensor. The oil temperature is important with regard to the load capacity of the engine, and it takes a lot longer to return to the 'green' zone than the water temperature. That means an oil temperature display can certainly help extend the service life of your engine.

Software

The software for the microcontroller on the Mini Mega Board is available on the *Elektor Electronics* website in the downloads for this article in the form of a ready-to-use hex file, which you only have to download into flash memory. The program has been compiled for an ATmega16 with an external 8-MHz crystal. The software was tested with chip version 2600 of the mOByDiC microcontroller in the OBD analyser. However, future versions shouldn't cause any changes in communications between the OBD analyser and the Mini Mega Board, so we don't anticipate any problems. If necessary, information about any relevant changes will be provided in the *Elektor Electronics* website forum and the Mailbox or Corrections & Updates section of the magazine.

For readers who not only want to build and use the stand-alone analyser, but also want to know how the software works, here's a brief explanation. Simple commands can be used to request the microcontroller of the OBD-2 Analyser to establish a connection to the vehicle and supply data blocks. These commands are described in the data sheet for the mOByDiC microcontroller. The communication process essentially consists of exchanging request and response bytes. The commands are very similar to those for the well-known ELM OBD ICs, so a glance at the (significantly more informative) data sheets for those devices can be helpful.

If you want to find out which data is supported by a particular vehicle, you should request the parameter identifiers (PIDs) by sending the byte string 02 01 00 (hexadecimal values). That particular series of bytes means that

you want to read data (02), you are working in Mode 1 (request readings), and you want to read out PID0. In response, you will receive (among other things) four data bytes for the first 32 supported PIDs. Many vehicles can also supply additional parameters, but they are not supported by the display unit in its present form.

After this, you can send the byte sequence 02 01 followed by a PID number to request the data block for the corresponding PID. The response will be something resembling what is shown in **Table 1**. The checksum calculation is quite simple: the byte values starting with the third byte onward are added, and the sum is then ANDed with FF to eliminate everything except the two least-significant hex digits.

The meanings of the individual bytes and the calculations necessary to generate the displayed readings are described for all the supported protocols in the ISO 15031-5 standard and its US counterpart SAE J1979. However, if you're not willing to spend £100 or so for your own copy, you can obtain more information from the well-known www.obd-2.de website, which is run by the author of the first OBD article in *Elektor Electronics* (October 2002).

Display configuration

The readings shown on the display depend on two factors. The first factor is which PIDs are available from vehicle in question, and the second factor is which of the available readings the user selects for the display configuration.

When the stand-alone analyser is switched on, it automatically determines which PIDs are supported by the vehicle and stores them in the EEPROM of the ATmega. If the analyser is connected to a different vehicle, it will automatically recognise any change in the available PIDs. In both cases, the unit will ask you to configure the display for the readings you want to have displayed (**Figure 4**). You can also enter the configuration mode whenever you wish by pressing and holding the PA0 button.

The display can show up to eight readings in short form (**Figure 5**) or four readings in long form (**Figure 6**). For each line, you can select either one reading in long form or two readings in short form. A blinking cursor indicates the position that is currently being

Step by Step

1. Before you start, you have to consider where and how you want to fit the two boards. One option is to fit them into an enclosure, as we did for the prototype shown in the photos. However, you might be able to find a suitable place for them in the car (measure carefully!), so all you need is a frame or front panel to cover the boards. In that regard, you should bear in mind that the OBD cable is relatively thick, and for cosmetic reasons it should probably be concealed from sight.

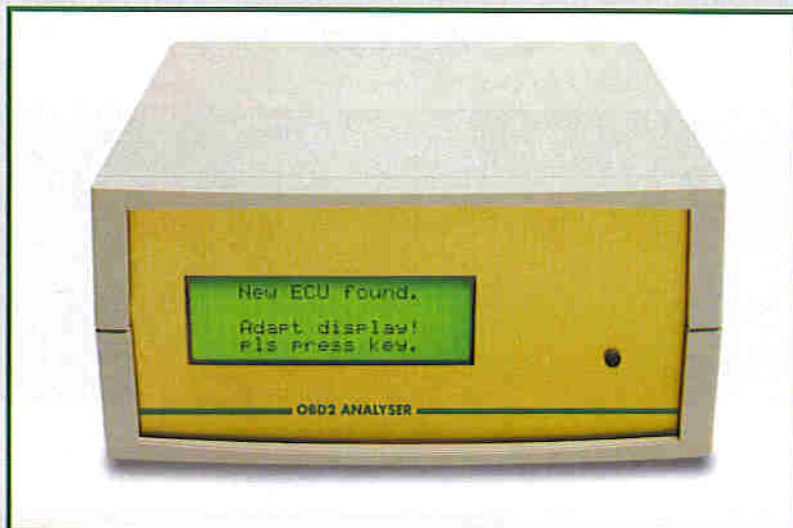


Figure 2 shows the construction of our prototype unit. The enclosure has a transparent acrylic sheet as a front panel. We painted it on the inside using spray paint. The opening for the display was masked off before painting. That's an easy way to produce a perfect display window without drilling, sawing or routing.

2. The two boards are joined together using a mounting plate (aluminium sheet or piece of circuit board). The mounting plate is located between the two boards. The Mini ATmega Board is placed at the front, and the OBD analyser board is placed at the rear. The mounting plate fits into the guide slots in the enclosure. With the enclosure we used for the prototype, 15-mm and 10-mm standoffs produced exactly the right spacing for the board assembly.

As an alternative, the OBD-2 Analyser board could be fitted horizontally in the enclosure. However, the vertical arrangement we used for the prototype has the advantage that it is easier to connect the OBD cable. If you use a straight D-sub connector for K2 instead of an angle connector, the cable can be plugged in directly. Of course, you can also omit K2 and solder the OBD-II cable directly to the board. In that case, you will have to cut off the D-sub connector at the end of the OBD-II cable, but you may have to do that anyhow if the OBD cable is not long enough. If the OBD vehicle connector is located somewhere other than near the steering wheel, such as under the seat, the cable will usually be too short. Then it's a good idea to use a different cable of sufficient length and fit the OBD-II plug at one end. The other end can be fitted with a 9-way D-sub connector or soldered directly to the OBD analyser board.

3. Only four connections are necessary between the two boards. Pins 2, 3 and 5 (ground) of K1 on the OBD-2 Analyser board must be connected to the same pins of K4 on the ATmega board. You should use stranded wire for this instead of solid wire to avoid a risk of breakage. The fourth connection is required to route the +12-V supply voltage to the ATmega board. If you omit K4 (power supply connector) on the ATmega board, you will have a connection point for +12 V that is connected to the anode of D2 via a circuit board track. On the OBD-2 board, +12 V is present at the anode of D3. You can thus connect the anode of D3 on the OBD board to the anode of D2 on the ATmega board.

Connect the display configuration pushbutton switch between PA0 (microcontroller pin 40) and +5 V.



Figure 4. Display contents after switch-on in the car.



Figure 5. Display screen showing four readings.



Figure 6. Up to eight readings can be displayed simultaneously.

Important Tips

- If the existing OBD-2 cable is too short and you cannot find nine-conductor screened cable to make a replacement cable, 8-conductor network cable (CAT5, preferably screened) is a readily available alternative. The missing ninth conductor (with respect to the OBD cable) is actually unnecessary, because you can use a single ground connection instead of two connections. Refer to the construction instructions for the OBD-2 Analyser in the July/August 2005 issue of *Elektor Electronics* for cable wiring details.
- If you already fitted the 9-way D-sub connector (K1) on the OBD analyser board, that doesn't have to present a problem for joining it to the ATmega board. Simply leave the connector in place and solder the three leads to the bottom of the ATmega board.
- If you already fitted the 9-way D-sub socket (K2) on the OBD analyser board, you shouldn't try to unsolder it intact, because the through-hole plating will usually not survive such an exercise. A better solution is to cut off the pins and then unsolder the pin remnants individually (hold the pin with pliers, heat the solder joint until the solder melts, and then pull the pin out).
- There is a new version of the OBD-2 software. Information about possible upgrades will be published on www.elektor-electronics.co.uk as soon as the details are known.

configured. If the cursor is at the start of a line, you can select the long form or the short form for displaying a reading. Pressing the button causes the next available reading or next display option to be shown. The display position is blanked after you have cycled through all the available PIDs, and pressing the button again causes the first reading option (protocol and available PIDs in hexadecimal notation) to be displayed. If you leave the button

What's in a car?

The question about which parameters you can read out from your car is best answered by your car. You can be sure of the answer after reading out the supported PIDs via the OBD-2 connector. After that, you can read out measured values for the PIDs supported by the ECU. Consult the author's website

www.blafusel.de/misc/obd2_pid.php

for specific information about the PIDs.

That website also provides another brilliantly simple feature: type the PID code read out by the stand-alone analyser into the search field to view full list of the supported functions. For example, the meaning of PID 983F8011 is shown in the following table.

| PID | Sensor |
|-----|----------------------------|
| 1 | System tests status |
| 4 | Calculated load value |
| 5 | Engine coolant temp |
| 11 | Intake manifold pressure |
| 12 | Engine RPM |
| 13 | Vehicle speed |
| 14 | Ignition timing advance |
| 15 | Air intake temperature |
| 16 | Air flow rate from MAF |
| 17 | Absolute throttle position |
| 28 | OBD standard |
| 32 | More PIDs |

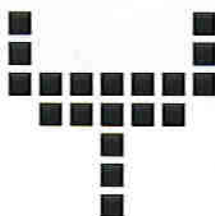
unpressed for a couple of seconds, the cursor will jump to the next display position. If you previously selected a long-form display, it will jump directly to the next line.

The configuration session is ended when the last available position has been configured. Only short-form outputs can be configured in the second half of each line.

Functions

As the stand-alone analyser is designed to be used as a digital add-on instrument for cars, its trouble diagnosis capabilities are limited. Storing text descriptions of trouble codes would vastly exceed the memory capacity of the ATmega16. Consequently, you will still have to use a laptop computer with diagnostic software to read and clear trouble codes. PID 2 is also not supported. That PID indicates which trouble codes caused trouble data to be stored in the engine control unit. However, the ATmega software does recognise any trouble indications that may occur if they can be read out in Mode 7. That actually includes all continually monitored systems. However, the fact that no trouble is indicated does not necessarily mean that no trouble codes have been stored. The actual trouble codes must be read using other OBD service modes, depending on the manufacturer.

The blinking spanner symbol



alternating with an inverted exclamation mark and 'Diagnosis' on the display indicates that a trouble code has been detected. You can then use the diagnostic software on your laptop to read out the trouble code and clear the trouble memory.

Of course, it's also possible to configure the unit to display PID1. If PID1 is supported by the engine control unit, it contains the number of pending exhaust-related trouble codes that caused the engine-trouble warning symbol (MIL, or 'malfunction indicator lamp') to be illuminated in the vehicle cockpit.

Construction information for autonomous analyser

Component population changes to ATmega board:

Not required: R1, K4, K6, S1, D1, JP1, JP3 and JP4 (do not fit), JP2 = wire link

Additionally required:

S3 = pushbutton (1 make contact) between PA0 and +5 V

Case, e.g. Bopla Unimas U160, size 160/133/75 mm

Programmed ATmega Controller, order code 050176-42 (HEX file contained in free download **050176-81.zip** from www.elektor-electronics.co.uk)

Configuration bits for ATmega: All bits unprogrammed ('1') except BOOTSZ0, BOOTSZ1, BODEN and SUT1.

Component population changes to OBD-2 Analyser board:

Do not fit K1; use straight pins version for K2, or do not mount it.

For kits and parts for this project,

see Elektor SHOP pages or www.elektor-electronics.co.uk

DIY ideas

A microcontroller system (such as the Mini Mega Board) connected to an OBD-2 Analyser naturally lends itself to a wide variety of further applications, including DIY projects. For instance, you could develop a data logging function using a standard SD

memory card so the data could subsequently be read out and analysed on your home PC. If you add GPS data storage to that, you have a true digital 'black box' in your car, which might be too much of a good thing in terms of monitoring.

(050176-2)

Links

www.elektor-electronics.co.uk (OBD forum)

www.blafusel.de/misc/obd2_scanned.php (vehicle list; the Elektor Electronics OBD-2 Analyser is shown there as 'mOByDiC interface')

www.ozenelektronik.com/upload/data/oe/moby2600.pdf (mOByDiC 2600 data sheet)

www.blafusel.de/misc/obd2_pid.php (PID calculation)

www.obd-2.de/tech_prog.html (Gerhard Müller's reading calculations for individual PIDs)

www.iso.org (ISO – International Organization for Standardization)

www.sae.org (SAE – Society of Automotive Engineers)

An ATmega by any other name...

As mentioned in the article, the Mini ATmega Board can be fitted with the ATmega16 (which has 16 KB of program memory) or the ATmega32 (which has 32 KB). The only difference between the two microcontrollers thus appears to be the size of the flash memory. At least, that's what we thought when we loaded code compiled for an ATmega16 into an ATmega32. When nothing at all worked and we were at our wit's end trying to figure out why, an attentive colleague pointed out that we had the wrong type of microcontroller. Now you know, so you don't have to try it for yourself.

OBD-2 in Elek

Your opinions on the car diagnostics circuit

Rarely have we received so many (enthusiastic) reactions from readers as those that were prompted by the publication of the OBD-2 analyser. Rarely were we asked so many questions and rarely did we have so few answers...

Karel Walraven

In the Double Summer Issue (the July/August issue) of 2005 we published an article concerning a DIY car analyser device, the OBD-2 Analyser.

With the aid of this circuit and a (laptop) computer it is possible to read information from your car such as temperature, speed, engine rev speed and instantaneous power. In addition, the screen also shows fault codes as soon as something goes wrong with your precious possession, so that you're no longer completely dependent on your mechanic.

The reports of models that were successfully read started to stream in.

Thousands of readers have built this circuit and it was unavoidable that we at the editorial offices were going to be inundated with questions. The most common question was obviously: I have such and such a car and will the circuit work with my car? To get some clarification we asked you to share your experiences on the forum on our website and

we received a massive response. At the moment we are sorting through all the responses so that it will be easier for you to get a quick overview. The most important issues we discuss here.

ektor Electronics

Hurray!

It appears that our car is our most precious possession, we cherish it and with every small deviation from normal driving behaviour or sound we are concerned. It is then not surprising that you as technically interested people are so happy with a circuit that allows you to diagnose possible defects. The comments on this topic varied from "Hurray, at last!" to "What a good idea".

Without doubt, the most common question was: "For which cars is the OBD-2 tester suitable?" In the original article we naturally mentioned that in principle petrol cars from 2001 and diesels from 2003 are fitted with an EOBD-interface. However, it appears to be a little sneakier than that. A few old hands in the trade butted into this discussion and the answer is: "New petrol cars from 2001 and new diesel models from 2003. If a model was already in production before that year, then it does NOT need to conform to the OBD-2 standard. And of course there are always the stubborn manufacturers who will do different if they can get away with it..." The pinch is therefore the word 'new'. This does not mean new from the factory but a new model or an upgraded model. So it is quite possible that the car with petrol engine that you bought in 2002 is not compatible!

It is not all gold that glitters...

We cannot ignore that a number of readers were disappointed with the design and had hoped for more. Your official car dealership has diagnostic equipment from the factory that costs thousands of Euros and provides a practically complete insight in all aspects of your car. We will be very honest here: Our OBD-2 analyser cannot compete with this, its capabilities are considerably more modest. But this is offset by a price tag that is also considerably more modest. Only those parameters (plus a few extras that differ for each car) that the manufacturer is required to make available according to European law, are displayed by our analyser. In particular with cars from earlier than 2000 it is sometimes disappointing how much (read: how little) can be read. "Not completely OBD-2 compliant. I can scan sensor values, but no DTCs are found. Unfortunately I do not know if there are no DTCs or if they cannot be read..."

In addition there were a large number of readers who wanted to use the OBD-2 circuit for engine tuning. Unfortunately it is not suitable for this. This is the domain of specialists! Consider that it is much easier to ruin your engine than it is to get more power from it! Cars from the Fiat group often provide measurement val-

PLEASE FIRST TURN
THE KEY ON PRIOR TO
CONNECTING MOBYDIE
OBDII/EOBD ADAPTER

ues that make no sense: "The PC communicates with my Fiat Stilo from 2003, but the measurement results make no sense at all. For example, water temperature 215. I have read on another site (Özen Elektronik) that Fiats from 2003 and earlier speak their own language and they were going to make a program that would work with this. Does anyone know any more of this? I'm keen

to find a good working program, because I have been struggling with this car from the beginning and really would like to read everything back. Fiat have been dragging the chain and are now saying that the warranty is over."

The company Özen does indeed have special chips for certain makes, including Fiat, Ford and Mazda. It is however best to go directly to the website for Özen Elektronik and to have a look around and, if necessary, to contact them.

"The PC communicates with my Fiat Stilo from 2003, but the measurement results make no sense at all."

VitalScan from Vital Engineering Ltd.

Vital Engineering

Live Sensor Data | Oxygen Sensors | Diagnostic Trouble Codes | Freeze Frame | Monitoring Tests | Options

MIL Status: Off
Number DTC's: 0 found
OBD Compliance: OBD II
ECU Protocol: ISO-9141
VIN Code: Not supplied by vehicle

About VitalScan

Cancel

| | |
|---|--|
| Fuel System 1 Status open loop | Air Flow Rate (MAF sensor) 0.1 g/s |
| Fuel System 2 Status open loop | Absolute Throttle Position 45.5% |
| Calculated Load Value 32.5% | Secondary air status Not supported |
| Coolant Temperature 45°C | O2 Sensor 1, Bank 1 0.610 V |
| Short Term Fuel Trim (Bank 1) -30.47% | O2 Sensor 1, Bank 2 0.625 V |
| Long Term Fuel Trim (Bank 1) -28.13% | |
| Short Term Fuel Trim (Bank 2) -25.78% | |
| Long Term Fuel Trim (Bank 2) -23.44% | |
| Engine RPM 6517 1/min | |
| Vehicle Speed 104 km/h | |
| Timing Advance -10.5° | |
| Intake Air Temperature 70° C | |

Scan Rate: 3.40/s
Main ECU address: 0X
Number of ECU's responded: 1

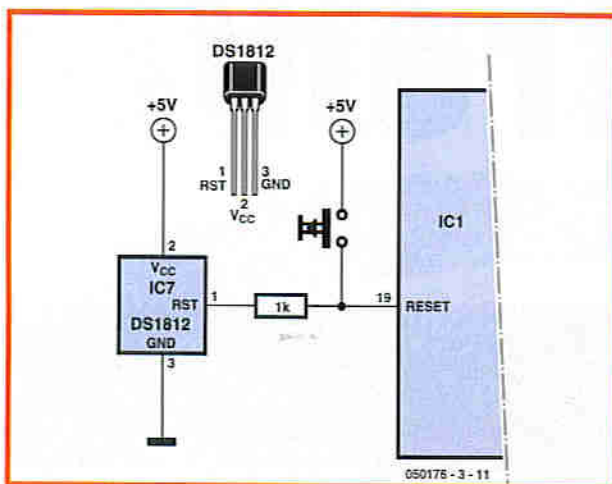


Figure 1.
In this way a reset button can be added to the circuit.

A few readers with non-European cars tried to connect to the WDS (Worldwide Diagnostics System) bus, but without positive results: "I was wondering if the OBD-2 kit will allow me change or write to the ECU using WDS?" But the answer from the forum was unanimous: "WDS requires separate PC software with its own interface. This will absolutely not work via OBD-2."

Who has succeeded in mounting the assembled PCB in its enclosure?

Good service!

From chipping come chips. A few circuits did not work and after checking them it appeared that the program was not burned properly in the microprocessor. We promptly replaced those and in general people were quite happy with that, particularly when everything was resolved quickly.

Reset perils

The early-bird buyers were confronted with start-up problems: a few components were missing here and there. This resulted in a drastic review of our internal buying procedures, after which the problem was solved. In addition it appeared that the microprocessor in the circuit required a relatively long reset-pulse in order to start reliably. That is why initially both C7 and the ZSH560

needed to be fitted. We had to replace the reset generator with a pin-compatible, more readily available type. C7 does not have to be fitted with the new type, a DS1812, because this already provides a long reset-pulse by itself.

The reports of models that were successfully read started to stream in. For a brief period there was some doubt over the jumper because it was not mentioned in the article. "We use this jumper when downloading the firmware. Leave it open for normal use. While the flash memory will not be erased if the jumper is in place, the chip will not run either."

In the meantime, owners of cars from the Volkswagen group had a few difficulties. They were plagued by start-up problems. But in the shortest possible time the answer was available in the forum: At power on the **red LED** has to light up. The moment the microprocessor starts to communicate the **yellow LED** will blink irregularly. All protocols are now tried one after the other. As soon as a valid protocol has been found the **green LED** lights up and the yellow LED will flash every now and then to indicate that communication is taking place. If no valid protocol has been found, then the yellow LED will light every 3 seconds. The search for the protocol is done only once after each

reset. If the electronics in the car is switched on later via the ignition key so that the protocol is not available early enough, then the OBD-2 analyser will wait indefinitely. There are a few remedies for this: Briefly unplug the OBD cable so that the microprocessor is reset after which the cable can be plugged back in, add a reset switch on the circuit board, or an on/off switch in the +12-V connection between the car and the analyser. In **Figure 1** you can see that adding a reset pushbutton is a straightforward job.

Other pitfalls

When working on a car, a laptop is obviously much more practical than a large PC with all its individual parts. However, laptops often have only USB connections and there was quickly the realisation that some types of USB/RS232 converters were not compatible enough. If the conversion from RS232 to USB is too slow then it is possible that the OBD-2 analyser does not find a valid protocol. In any case, the converters from the company Özen Elektronik work well and all converters with FTDI chips work without problems.

About the construction

"Who has succeeded in fitting the assembled PCB in its enclosure without removing the front?" a reader asked. The answer came from both the *Elektor Electronics* lab as well as from a reader: "I have done it differently. Place the PCB on the upside-down lid and place the enclosure on top, so that the holes line up. Then mark the width of the connectors. After that, place the enclosure with the edge on the lid and mark the height of the connectors. Cut out or file away the marked parts. When you place the PCB on the lid and the enclosure over the top and screw them together, the PCB is then held in place by the connectors. Sliding or rattling is then not a problem."

(050176-3)

Suitable programs

In the forum the following programs have been mentioned that appear to work well with the OBD-2 hardware:

| | |
|------------------------|----------------------|
| MCI 1.2b | Digimoto lite |
| Mobytester plus | OBD2Spy |
| Scanmaster | VitalScan |

All these programs can be found at <http://www.ozenelektronik.com>. You have to log in and then select Download/Mobydic.

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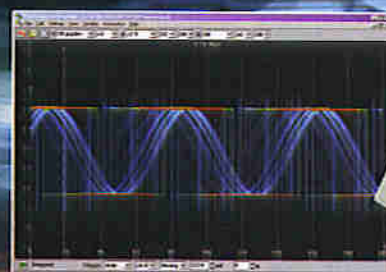
www.spice-software.com



PicoScope 3000 Series PC Oscilloscopes

The PicoScope 3000 series oscilloscopes are the latest offerings from the market leader in PC oscilloscopes combining high bandwidths with large buffer memories. Using the latest advances in electronics, the oscilloscopes connect to the USB port of any modern PC, making full use of the PCs' processing capabilities, large screens and familiar graphical user interfaces.

- High performance: **10GS/s** sampling rate & **200MHz** bandwidth
- **1MB** buffer memory
- High speed **USB 2.0** interface
- Advanced display & trigger modes
- Compact & portable
- Supplied with PicoScope & PicoLog software



| PicoScope | 3204 | 3205 | 3206 |
|-----------------------------|---------------------|------------------------------|-----------------------|
| Bandwidth | 50MHz | 100MHz | 200MHz |
| Sampling rate (realtime) | 2.5GS/s | 9GS/s | 10GS/s |
| Sampling rate (single shot) | 50MS/s | 100MS/s | 200MS/s |
| Channels | 2+Ext trigger | 2+Ext trigger/Sig gen | 2+Ext trigger/Sig gen |
| Oscilloscope timebases | 5ns/div to 50µs/div | 2ns/div to 50µs/div | 1ns/div to 50µs/div |
| Timebase accuracy | 50ppm | 50ppm | 50ppm |
| Spectrum range | 0 to 25MHz | 0 to 50MHz | 0 to 100MHz |
| Buffer memory size | 256KB | 512KB | 1MB |
| Resolution / accuracy | | 8 bits / 3% | |
| Range | | ±100mV to ±20V | |
| PC Connection | | USB 2.0 (USB 1.1 compatible) | |


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FPGA Course (2)

Paul Goossens



$$\begin{aligned}
 f(x) &= \cos(yx), \quad y \in \mathbb{R} \setminus \mathbb{Z}, \quad [-\pi, \pi] \quad (\text{cos(4\pi \cdot x) is included, /sin(\pi x)}) \\
 \text{Fourier Series: } f(x) &= \frac{a_0}{2} + \sum_{k=1}^{\infty} (a_k \cos kx + b_k \sin kx), \quad b_k = 0 \text{ since } f(x) \text{ is even} \\
 a_k &= \frac{1}{\pi} \int_{-\pi}^{\pi} \cos yx \cos kx \, dx = \frac{1}{\pi} \int_{-\pi}^{\pi} \frac{1}{2} [\cos(yx-kx) + \cos(yx+kx)] \, dx \\
 (\cos x \cdot \cos y &= \frac{1}{2} [\cos(x-y) + \cos(x+y)], \quad \sin(-x) = -\sin(x)) \\
 &= \frac{1}{2\pi} \left[\frac{\sin((y-k)\pi)}{y-k} + \frac{\sin((y+k)\pi)}{y+k} \right]_{-\pi}^{\pi} = \frac{1}{\pi} \left(\frac{\sin((y-k)\pi)}{y-k} + \frac{\sin((y+k)\pi)}{y+k} \right) \\
 &= \frac{1}{\pi} \left(\frac{(y+k)(\sin y \cos k\pi - \sin k\pi \cos y) + (y-k)(\sin y \cos k\pi + \sin k\pi \cos y)}{(y-k)(y+k)} \right) \\
 (\sin(a+b) &= \sin a \cos b + \sin b \cos a, \quad \sin(a-b) = \sin a \cos b - \sin b \cos a) \\
 a_k &= \frac{1}{\pi} \left(\frac{y \sin(y\pi(-1)^k + k \sin(y\pi(-1)^k + y \sin(y\pi(-1)^k - k \sin(y\pi(-1)^k)}{y^2 - k^2} \right)
 \end{aligned}$$

In the first article of this series, we described the basic components of digital electronics and put them to use. In this second instalment, we introduce some components that are a bit more complicated and perform a few simple calculations using digital logic.

After reading the first part of this series, you should know enough about the basic components of digital electronics. In this instalment, we use them to do things that are a bit more useful.

Memory

Let's start off by looking at the most commonly used type of memory element: the flip-flop.

The simplest type of flip-flop is the 'set-reset' (SR) flip-flop. It has two inputs (Set and Reset) and one or two outputs (Q and \bar{Q}). When the Set input goes to '1', the Q output also goes to '1'. That state remains unchanged even if the Set input returns to '0'. When the Reset input goes to '1', the

Q output will go to '0'. That state also remains stable after the Reset input returns to '0'. The response of the flip-flop is undefined if the Set and Reset inputs are both '1'. That is regarded as a forbidden state that must never occur.

Figure 1 shows a schematic diagram for this type of flip-flop. It is constructed from standard components. IC1 and IC2 are NAND gates (a NAND gate is an AND gate with an inverter at its output, and an inverted output is marked by a small circle or diagonal line at the output).

Truth table

How can this be translated into a truth table? The answer is shown in Figure 2.

The SR flip-flop is shown at the far left. The associated truth table shows output Q_{N+1} instead of output Q. That indicates that this column shows the state of the output after the input signals have been processed. In some cases, the output state also depends on the previous state of the output. That is indicated here by Q_N .

Advanced forms

A slightly more advanced form of flip-flop is the type known as a 'latch'. Its truth table is shown in Figure 2. This type of flip-flop has two inputs – D ('data') and Gate – and one output (Q). The Q output is the same as the D input as long as the Gate input is '1'. When the Gate input goes to '0', the Q

Part 2: Memories and calculations

output retains its value regardless of the state of the D input. It effectively stores the state of the D input at the time when the Gate signal became '0'. The next step brings us to the D-type flip-flop. The output of this type of flip-flop assumes the state of the input when the signal on the CLK input changes from '0' to '1'. That is indicated in the truth table by an arrow. The output remains unchanged as long as the CLK input stays at '1' or '0'.

The D-type flip-flop can be expanded with a variety of additional inputs. **Figure 2** shows such an expanded D-type flip-flop. It has three inputs in addition to the D and CLK inputs: SET, RESET and CE. The SET and RESET inputs perform the same functions as with an SR flip-flop. The clock enable (CE) input of this flip-flop controls the response to the clock signal: a rising edge on the CLK input has no effect if the CE input is not in the High state.

Trying it out

The **ex5** folder (included in the downloads for the second instalment on the *Elektor Electronics* website under Magazine/May) contains an example with various types of flip-flops. The RS flip-flop and the latch are implemented in the example in the form of logic gates. You can use the example to convince yourself that these functions can be constructed using ordinary gates. The other types of flip-flops are taken from the Quartus library.

You can use the pushbuttons to experimentally test the operation of the various types of flip-flops.

VHDL

Things really start to get interesting when you use VHDL for flip-flops. The nice thing about VHDL is that you can describe a design instead of building it with small logic elements. The program uses the description to design logic that does exactly what your description says.

Before we get into the details of the design, you need to know how the

VHDL compiler reads your description. A VHDL file describes how the outputs (and the internal signals, if any) have to respond to the inputs. For this purpose, the VHDL compiler applies every conceivable combination of input signals (in virtual form) to the inputs of your design. For each change to the input signals, the compiler attempts to determine how the outputs must respond.

That all sounds a bit abstract, but the following example should help clarify what it means.

Structure

The structure of a simple VHDL file is shown in **Figure 3**. The first thing you have to do is make the standard library 'visible' to the compiler. Several basic functions for digital logic are defined in the standard library.

After that, you must declare at least one entity. You can think of an entity as something like a particular type of IC. In the entity declaration, you give the entity a name (a 'type number') and define the inputs and outputs of your 'virtual IC'.

After that comes the architecture section, which describes how the entity functions.

An example

We can use an example to show exactly how all this works. The project for this example is located in the **ex6** folder. Double-click on the block named **Latch_VHDL**. That will open the VHDL file that describes how this particular bit of logic operates.

The declaration of an entity named **Latch_VHDL** starts on line 29. The inputs CLK and DATA and an output named Q are declared here. These signals are all of type *std_logic*. That data type indicates that they are digital signals. We'll describe some other types later on.

The description of how the **Latch_VHDL** entity has to respond to its input signals starts on line 44.

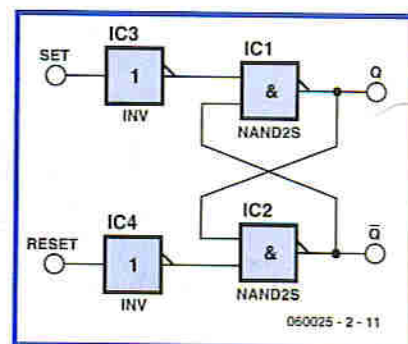


Figure 1. Basic configuration of a flip-flop using four NAND gates.

Processes

You have already seen that Boolean equations can be used to describe functions. An even more powerful approach is to use processes. In a process, you can specify the value(s) that one or more signals must assume under various circumstances.

The **process** keyword is followed by a sensitivity list. Each time the compiler changes the (virtual) value of any of the signal in this list, it must evaluate the code segment of the process. We'll explain this a bit later on.

If then else

The keyword **if** appears on line 51. It will doubtless be familiar to the programmers among our readers. This line says that if the signal on the CLK input is '1', the compiler must evaluate the code until it encounters an **end if** statement.

In this case there is only line in between, and it contains the statement **Q <= DATA;**. The whole process is terminated by an **end process** statement, and the end of the description is declared in line 56.

Evaluation

When the compiler evaluates the code segment, it discovers that the Q output must be the same as the DATA input as long as CLK is '1'. Nothing must happen when CLK is not '1', which

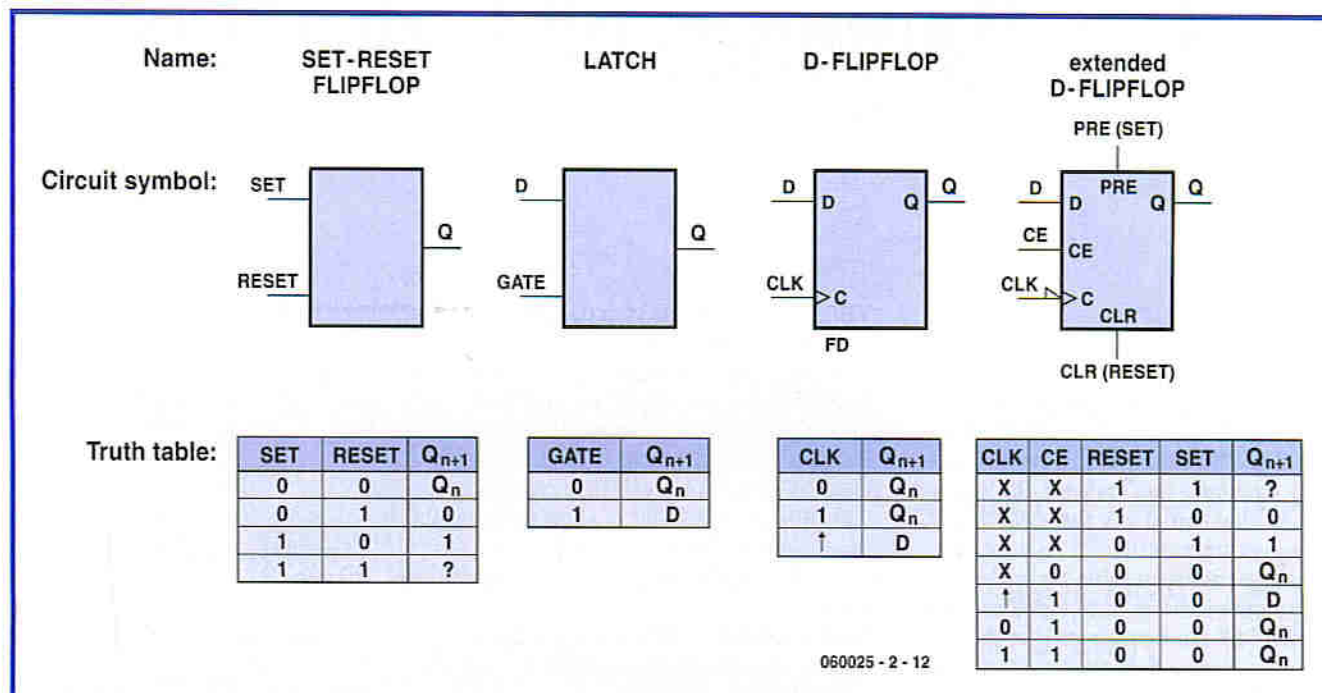


Figure 2. Various types of flip-flops and their truth tables.

means Q must not change. That shows how you can design a latch in VHDL.

D-type flip-flop

Now open the file `D_ff_VHDL` in the same way as before. Here you will see a similar file with a few crucial differences.

A new construction for the *if* statement appears on line 51. The construction *clk'event* is only true when the CLK signal changes. The construction *clk'event and clk='1'* is thus only true when a positive edge (low-to-high transition) is present at the CLK input. The Q output will only assume the value of the DATA input in that situation. In all other situations, Q will

remains the same. This is thus a description of a D-type flip-flop.

Another D-type flip-flop

The second example of a D-type flip-flop has two additional inputs: SET and RESET. In the accompanying VHDL code, you can see that a test is first made to see whether *reset* is '1'. If it is, the output is set to '0'. Otherwise the state of the *set* input is examined. If it is '1', the output will go high. If the set and reset inputs are both not '1', a test is made to see whether the *clk* signal exhibits a rising edge (just as in the previous example for a D-type flip-flop).

If you refer back at the start of the

process, you will see that the signals *clk*, *set* and *reset* appear in the sensitivity list. Output Q can change if any one of these signals changes state. The *set* and *reset* inputs act asynchronously to the *clk* input. In other words, the device does not require a rising edge on the *clk* input to respond to a *set* or *reset* command.

You should also note that *reset* has a higher priority than *set* for this flip-flop. If *set* and *reset* are both '1' at the same time, *reset* will win the contest and the output will go to '0'.

Arithmetic

The examples up to now have used signals of type *std_logic*. An extension

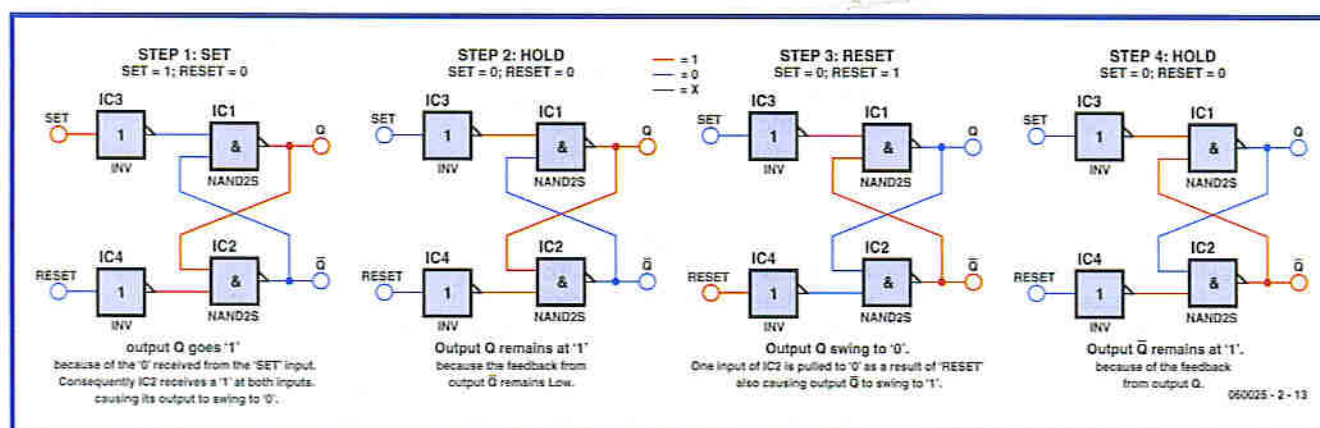


Figure 3. The various states of a flip-flop.

of that type is *std_logic_vector*, which we abbreviate as *S_L_V* for the remainder of this article. That type consists of a set of signals of type *std_logic*. You can use such a set of signals to represent a number (see inset).

There is also a type known as *natural*. It encompasses all positive whole numbers (integers). Doing arithmetic with signals of type *natural* is quite easy. You can use them for addition, subtraction, multiplication and division in VHDL.

That capability is used in **ex7** to create a pulse waveform with a frequency of 1 kHz, derived from a 50-MHz clock.

Open the example and double-click on the block named *pulse_generator*. In the associated VHDL code, you can see how a signal of type *natural* is used for counting. First the ports are defined: a input signal named *clk* and an output signal named *slow_clk*. In the associated VHDL code, you can see how a signal of type *natural* is used for counting. This signal must be able to hold the range of values from 0 to 500,000 inclusive. The VHDL code uses these numbers to determine how many bits are required.

In the associated **procedure**, a test is made on each rising edge of *clk* to determine whether the value of the *counter* signal has reached the maximum value (499,999). If it has, the new value is set to '0' and the *slow_clk* output is set to '1'. In all other cases, the value of *counter* is incremented by 1 and the *slow_clk* output is set to '0'.

The net result is that the output goes to '1' after 500,000 clock pulses. On the next clock pulse, it returns to '0' and the cycle starts again from the beginning. If a 50-MHz clock signal is applied to the *clk* input, the output will briefly go to '1' a thousand times per second.

The VHDL code for *calculate_sum* demonstrates something else that's new. First, line 25 shows that an additional library is necessary – the *numeric_std* library. A variety of arithmetic operations and conversions are defined in that library.

The input signal *a* is declared in line 34. The expression *STD_LOGIC_VECTOR (3 downto 0)* says that this signal set consists of four signals: *a(3)*, *a(2)*, *a(1)* and *a(0)*. You already know that a signal set can be used to represent numbers. Making calculations with *S_L_V* is a bit more roundabout. The functions of addition, subtraction and so on are not defined for type *S_L_V* in

Binary arithmetic

Numbers can be represented using one or more digital signals. As binary signals can have only two states (1 or 0), the binary number system must be used in such cases. In normal life, we use the decimal number system (base 10). In the decimal system, a set of three numerals can be used to represent 10^3 (1000) different numbers (0–999).

In the binary system, a set of three digits (signals) can represent a total of 2^3 ($2 \times 2 \times 2 = 8$) values ranging from '000' to '111', or 0 to 7 in decimal notation.

Sample calculation

The number '821' in decimal notation consists of $8 \times 10^2 + 2 \times 10^1 + 1 \times 10^0$. Similarly, the number '101' in binary notation consists of $1 \times 2^2 + 0 \times 2^1 + 1 \times 2^0 = 1 \times 4 + 1 \times 1 = 5$ in decimal notation.

You may find the following table useful for converting between binary and decimal numbers.

| $2^3=8$ | $2^2=4$ | $2^1=2$ | $2^0=1$ | Decimal | Hexadecimal |
|---------|---------|---------|---------|---------|-------------|
| 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 1 | 1 |
| 0 | 0 | 1 | 0 | 2 | 2 |
| 0 | 0 | 1 | 1 | 3 | 3 |
| 0 | 1 | 0 | 0 | 4 | 4 |
| 0 | 1 | 0 | 1 | 5 | 5 |
| 0 | 1 | 1 | 0 | 6 | 6 |
| 0 | 1 | 1 | 1 | 7 | 7 |
| 1 | 0 | 0 | 0 | 8 | 8 |
| 1 | 0 | 0 | 1 | 9 | 9 |
| 1 | 0 | 1 | 0 | 10 | A |
| 1 | 0 | 1 | 1 | 11 | B |
| 1 | 1 | 0 | 0 | 12 | C |
| 1 | 1 | 0 | 1 | 13 | D |
| 1 | 1 | 1 | 0 | 14 | E |
| 1 | 1 | 1 | 1 | 15 | F |

Hexadecimal notation

Relatively large binary numbers are generally difficult to comprehend due to the large number of ones and zeros. Hexadecimal notation (base-16 number system) can be used to make them easier to understand. That notation uses the numerals 0–9 and the letters A–F, with A representing the decimal value 10, B the decimal value 11, and so on. See also our Hexadoku puzzle! A single character can thus be used to represent 16 different values. That corresponds to four bits in the binary system.

Active High and Active Low

Many components have 'active Low' inputs. That means the input is 'active' when the logic level at the input is Low.

For instance, a flip-flop with an active-low Reset will be reset when a logic Low signal is applied to the Reset input. Active-low inputs can be recognised by the small circle or triangle at the input concerned. An 'inversion bar' can also be placed above the name of the input to indicate that it is active low, such as `RESET`.

It's also possible for outputs to be active Low. Such outputs can similarly be recognised by the inversion bar over the name or a small circle or slanted line at the output.

VHDL. However, they are defined in the numeric_std library for some other types, including *unsigned*. Several useful conversion routines are also located in that library.

The expression *UNSIGNED* (a) converts the set of signals *a(3)...a(0)* to type *unsigned*.

A set of signals of type *unsigned* can be converted to type *S_L_V* in the same manner.

You can see all that on line 49. There the two input signals *a* and *b* (each of which is a signal set) are converted to type *unsigned*. The two values are added together, which yields a result of type *unsigned*. Finally, that result is converted to type *S_L_V*. These signals are also linked to the *SUM* output. This thus amounts to a simple addition function.

A subtraction function is described in the same manner in *calculate_dif*.

Busses

The two blocks are interconnected in the Quartus schematic by several signal lines originating from dipswitch S5. The input port, *DIPSWITCH[3..0]*, consists of four independent input lines with the designations *DIPSWITCH[3]*, *DIPSWITCH[2]*, etc. This deviates from the VHDL standard with regard to the notation for a set of signals.

This set of signal lines can also be connected using a bus instead of individ-

ual signal lines. You can draw a bus in Quartus by using the Bus Tool instead of the Node Tool. A bus is shown in a schematic diagram with a thicker line than individual signal lines.

The schematic diagram here has several busses, some of which are connected to a port at only one end. Quartus regards all signals with the same name as being linked together, so it isn't necessary to connect all the associated lines together.

Multiplexing

The 7-segment displays must be driven one at a time. Only one segment can be on at any given time. This sequential drive is provided by the *sequencer* block.

In the *count* process in *sequencer.vhd*, you can see that the *internal_select* signal is incremented by 1 each time each time a rising edge occurs on the *clk* line when the *clk_en* input is '1'. In the schematic, *clk_en* is connected to a signal line that goes to '1' once every 500,000 clock pulses. As a result, the *internal_select* signal is incremented 100 times per second (50 MHz ÷ 500,000).

Line 66 shows a new feature of VHDL. It says that the *sel1* signal must go to '1' if the counter value is '0', and otherwise the *sel1* output must be '0'. Signals *sel2* to *sel4* are generated in the same way. As a result, these outputs

go to '1' sequentially. The counter value is also output via the *sel* signal (line 72).

Signals *sel1-sel4* drive transistors T1-T4 on the prototyping board to enable the various groups of LED segments.

In step

This example is designed to display four different numbers. The numbers must be output sequentially, synchronised with the drive signals for transistors T1-T4. The *sel[1..0]* signals from the sequencer can be used for this purpose.

The *mux* block takes care of all this. The *current* output is enabled by the four inputs (*val1*, *val2*, *sum* and *dif*) according to the value of the *sel* signal. The keyword *when* appears in line 52 of the associated VHDL code. In that line, the *current* output is enabled by the *val1* input if the value of *sel* is '00' (0). Similarly, the output is enabled by *val2* if *sel* is equal to '01' (1), and so on. Once again, the final enable is provided here by the *else* keyword.

Decoding

The *current* output contains the value to be shown on the display. This value is also nicely synchronised with the drive signals for the individual groups of LED segments.

The value of *current* is available in binary form, so the individual LED segments must be driven based on this binary code. The value '1' must be shown on a 7-segment display by driving segments b and c. To display the value '0', segments a-f must be driven. That means the binary values must be converted into the proper drive signals for the various segments.

This last bit of processing is handled by the block named to *seven_segment*. In the VHDL code for that block, you will see another new keyword: *case*. The line *CASE val IS* says that the value of *val* determines how the following bit of code is to be processed. You could read line 50 as 'if *val* has a value of '0000', then the following must happen'. The software will then evaluate the subsequent lines of code until it encounters the next *when* keyword.

In line 51, you can see that this causes the value '1111110' to be assigned to the *segments_out* output. In other words, segments a-f are driven on and segment g is not driven. The numerals 1-9 and the digits A-F (for hexadecimal

Earlier in this series

Versatile FPGA Module, *Elektor Electronics* March 2006.

FPGA Prototyping Board, *Elektor Electronics* March 2006.

FPGA Course (1), *Elektor Electronics* April 2006 (with free downloads).

mal display) are decoded in a similar manner. Finally, the end of the case statement is indicated in line 84.

Testing

The best way to understand the previous explanation is to try it out in practice. To do so, program the FPGA unit with the example program in **ex7**. If everything goes right, you will see several numbers appear on the 7-segment displays.

few changes to the code of the example. For instance, you can change the order of the numbers, or instead of calculating the difference of two numbers, you can calculate and display the product of the two values (multiply = * in VHDL).

The **ex8** folder con-

Digital arithmetic in practice

All digital devices calculate using the binary number system, even if their users are not aware of the fact. The arithmetic processes are often considerably more complex than simple addition.

Your personal calculator is a good example of what can be done with digital arithmetic. Besides normal arithmetic operations, it can also be used for relatively complex calculations such as sine, cosine, square root, and so on.

An example of a more practical application of this arithmetic capability is a digital control system for a rocket. A considerable amount of real-time calculation is necessary to accurately send a rocket into space along its intended path.

Yet another example is your DVD player. It takes a lot of mathematical calculations to transform the compressed data on a DVD into a nice picture on your screen. All those calculations are performed by a processor. Naturally, that's a digital processor, and it calculates (lightning fast) using only binary numbers.

You can use switches 0-3 of S5 to assign a value to *val1*. It will be shown on the display at the far left. You can similarly use switches 4-7 to assign a value to the second number.

The third number on the display shows the result of adding the two input values, and the last number shows the difference between the two values.

Experimenting

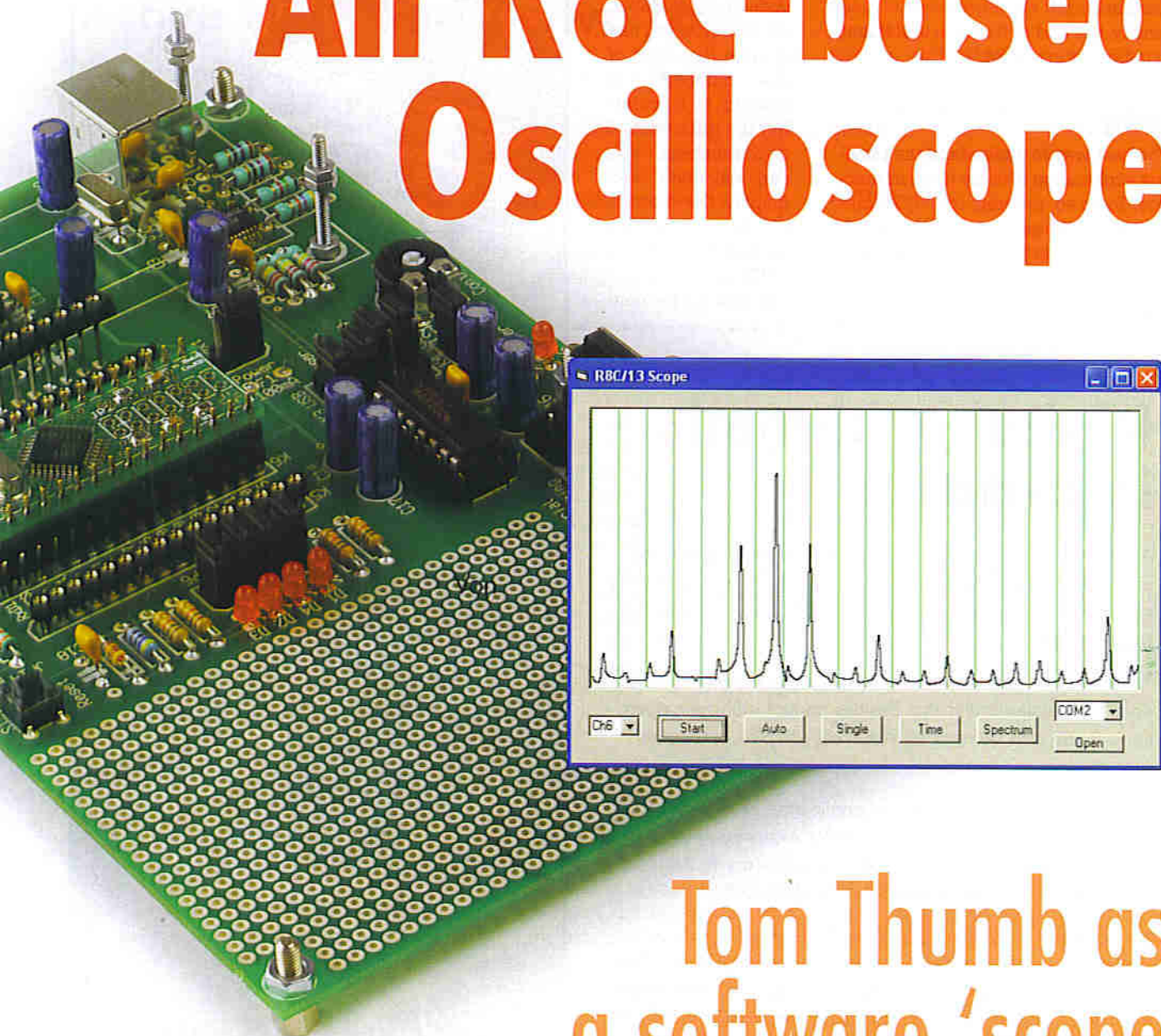
To familiarise yourself with this approach to designing, try making a

tains several other folders with even more examples. Now that you've read this article, you should be able to figure out how these examples work. Try out each of them in turn, and study the associated code to discover how they work. That's the only way to become fluent in VHDL!

(060025-2)



An R8C-based Oscilloscope



Tom Thumb as a software 'scope

Burkhard Kainka and Olaf Kaluza

The previous instalments of our R8C 'Tom Thumb' series concentrated on explaining the basic functions of the R8/13 system. Now it's time to look at some real applications. The objective here is to develop a small oscilloscope in two forms: first on a PC, and second as a stand-alone device with its own graphic display.

Many 'real' PC oscilloscopes can achieve sampling rates of up to 20 MHz, but usually with 8-bit resolution. Simple implementations using a sound card typically have a sampling rate of 48 kHz or so. However, sound cards cannot process DC signals. One way to remedy this situa-

tion is to use a microcontroller with an A/D converter.

A PC storage oscilloscope

The objective is to have the R8C/13 take samples as rapidly as possible, buffer the measured values in RAM,

and then transmit them to the PC at a high baud rate. To keep the conversion time short, the A/D converter will be operated in 8-bit mode. In theory, the maximum memory depth is nearly 1000 bytes. However, only 500 bytes are used here, because a conflict with the memory demands of the KD30

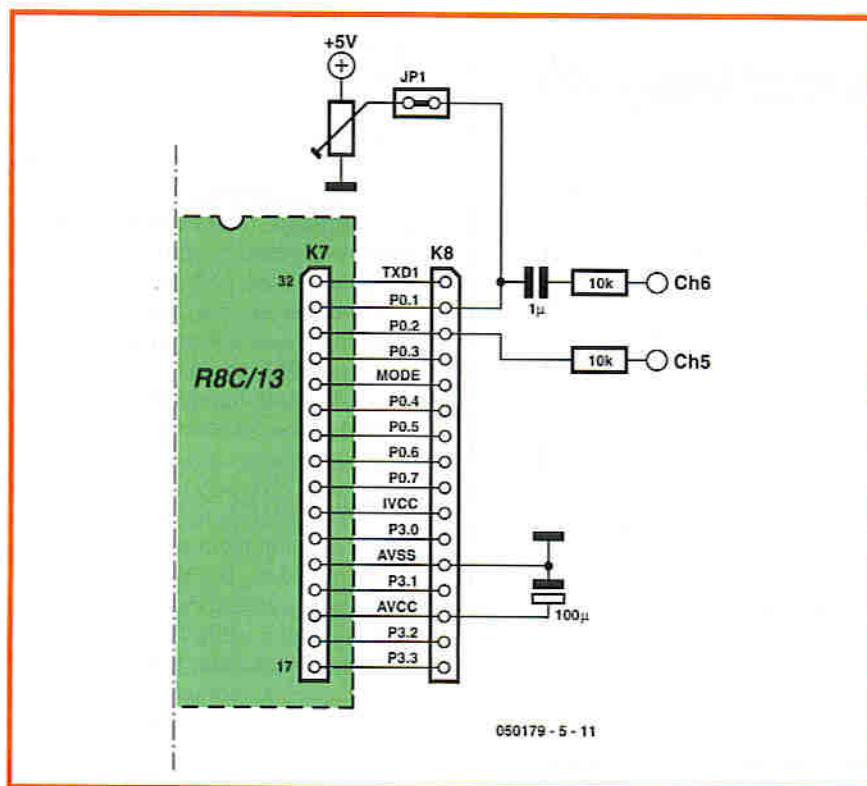


Figure 1. The analogue inputs are protected by 10-k Ω resistors.

Listing 1

Data acquisition using the R8C/13 ('Scope1' project)

```
unsigned char ad_buf[500];

unsigned char ad_in(unsigned char ch)
{
    adcon0 = 0x80 + ch;           //Port P0 group
    adcon1 = 0x20;                //8-bit mode
    adst = 1;                     //Conversion start
    while(adst == 1){}           //Wait A/D conversion
    return ad;                    //AD value
}

void sample(unsigned int ch)
{
    unsigned int adr;
    for (adr = 0; adr < 500; adr++)
    {
        ad_buf[adr] = ad_in(ch);
    }
    for (adr = 0; adr < 500; adr++)
    {
        sendTxd0(ad_buf[adr]);
    }
}

void main(void)
{
    while (1)
    {
        sample(receiveRxd0());
    }
}
```

debugger could easily arise with a larger data volume.

The 'Scope1' project (see Listing 1) uses the UART0 serial interface port of the microcontroller. That leaves UART1 free for the debugger. The data transmission rate is set to 38,400 baud. The A/D converter can use the seven available channels (AN0-AN6), which are located in port 0. As the LCD is not used for this application, all seven channels are available.

Data communication is governed by the following protocol. The PC first transmits a single byte containing the desired channel number (0-6). The R8C/13 then takes 500 individual samples and stores the results in its data buffer. At the end of the measurement process, all 500 bytes are transferred directly to the PC. The sampling rate is approximately 100 kHz, which is suitable for general measurement tasks.

It is highly recommended to fit 10-k Ω protective resistors in series with the inputs of the individual channels (Figure 1). That will avoid any risk of damage to the microcontroller if an excessive voltage is accidentally applied to an input. The potentiometer connected to analogue channel 6 can be put to good use as a zero-reference control for measuring AC signals. Additional smoothing of the supply voltage may be necessary, because the voltage drop across the Polyswitch fuse (F1) creates noise on the V_{CC} line and thus on the reference voltage for the A/D converter. A 100- μ F electrolytic capacitor connected to V_{CC} will provide adequate smoothing.

Displaying measurement data in Visual Basic

On the PC side, a small Visual Basic (VB) program looks after displaying the measured values. The VB project was generated using VB5, and it can also

Listing 2

Data reception in VB

```
Private Sub Command1_Click()
    TIMEINIT
    SENDBYTE 1 :... Ch
    DELAY 200
    For n = 0 To 500
        a = READBYTE()
        Ch1(n) = Int(a)
    Next n
    Plot
End Sub
```

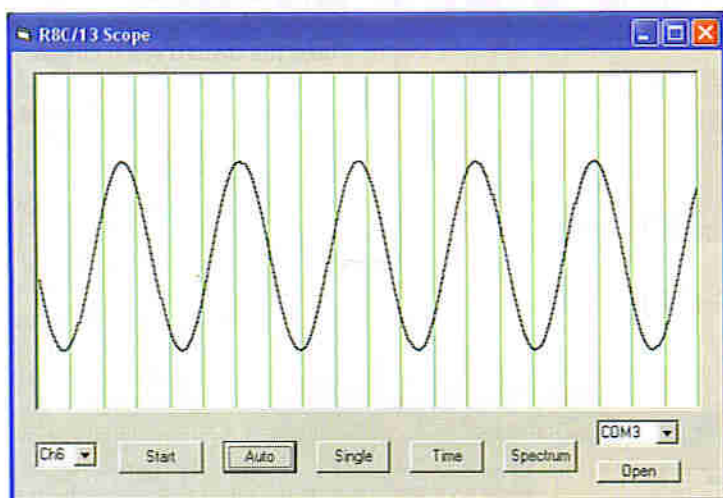



Figure 2. An oscillogram on the PC monitor.

be compiled using VB6. The accompanying .exe file was generated using VB6. The user selects the desired input channel and starts a measurement session by pressing the 'Start' button. Automatic repetitive measurements can be enabled instead by pressing 'Auto' (see Figure 2). The 'Spectrum' button selects a Fourier spectrum display as described in the next section.

The procedure for requesting and receiving the data (Listing 2) stores the incoming 500 bytes in a data array designated Ch1(n), from which the data is passed to the output routine ('Plot').

Fourier analysis

When measurement data is available in digital form, the spectral components of the signal can be calculated and displayed using Fourier analysis. In simplified terms, that consists of multiplying the actual waveform by a sine wave with a known frequency.

Sample projects on the Web

The serial interface and A/D converter are highly versatile in use, as can be seen from several projects described on the R8C Info pages (accessible from the Quick Service menu on www.elektor-electronics.co.uk). You can also download the sample projects from the Service page. If you're looking for a new application for your microcontroller, you're bound to find something useful there. Contributions are welcomed!

Figure caption: A PC oscilloscope using the R8C/13

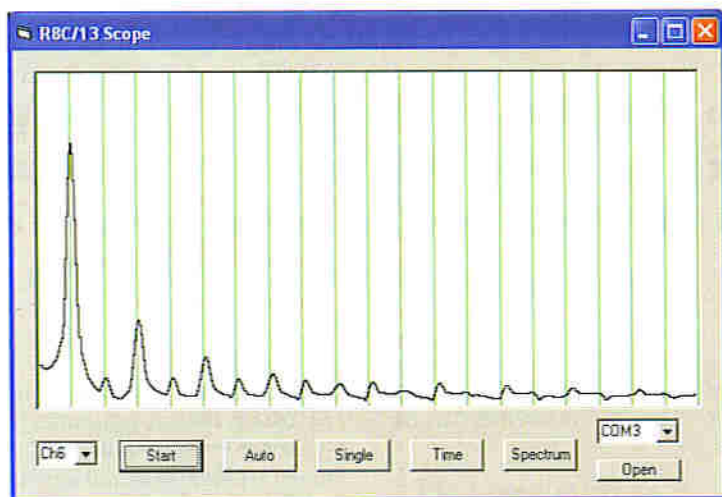
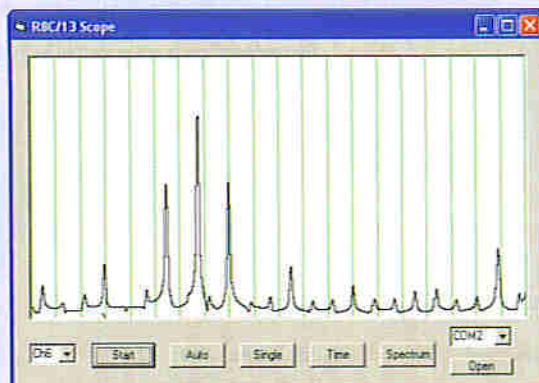


Figure 3. Frequency spectrum of a 1-kHz square-wave signal.

The result indicates the amplitude of the signal component at that frequency that is present in the original signal. However, this requires a considerable amount of computation. If 500 samples are present, 500 sine-wave values must be calculated for each frequency and multiplied by the measurement data. The whole process must actually be performed twice, because the unknown phase offset of the measured signal makes it necessary to perform two analyses with a phase difference of 90 degrees. After that, the two output values must be processed by vector addition to obtain their joint magnitude. To avoid generating measurement errors due to the abrupt termination of the signal at the edges of the measurement window, it is recommended to first process the measurement data using a rounded window function.

This analysis is normally performed

with a 'fast Fourier transform' (FFT) using the butterfly algorithm. Although the FFT may be fast, it is complicated and requires quite a lot of memory. Nevertheless, our objective later on will be to copy the algorithm used for this purpose as exactly as possible from the VB code into C code compiled for the R8C. Consequently, we use a simple digital Fourier transform (DFT) here. **Listing 3** shows the conversion routine that processes the time sequence in Ch1 into a frequency spectrum in Ch2. The edges are rounded using a Hann window before the actual transformation takes place. **Figure 3** shows the spectrum of a 1-kHz square-wave signal as displayed in the program window.

Graphic LCD

The graphic LCD really turns the R8C/13 into a powerful system. With it in place, the PC is only needed for programming, and an application such as the simple oscilloscope described here can run fully independently on the microcontroller system. Here we use a type 64128E from Displaytech (distributed by Glyn, and available from AK MODUL-BUS and Geist Electronic as well). The display has a resolution of 128 × 64 pixels and requires a supply voltage in the range of 3 V to 3.6 V (maximum). It can be driven either in parallel or serially via an SPI interface. Parallel operation would occupy too many port lines in this case. The LCD is thus operated in serial mode here, which also simplifies the connection.

The sample project described here ('LCD64128E') specifically requires the indicated display type. Unfortunately, there is no commonly used type of 'standard' controller for graphic displays, but instead a wide variety of types. In this case, the controller is the KS0713 from Samsung. The specified 3-V operating voltage means that the control lines must also be driven using 3-V signal levels. There are two ways to do that. One way is to use a 3-V supply voltage for the R8C/13 as well, and the other way is to use suitable level converters – which in the simplest case can be voltage dividers formed by pairs of resistors. These two options are illustrated in **Figures 4** and **5**.

An extra 3.3-V voltage regulator can be used to operate the R8C/13 at a reduced voltage, as shown in **Figure 5**. However, there's an even simpler option. For initial testing, it's sufficient to connect two 1N4004 diodes in series

Listing 3

Fourier analysis in VB

```
Private Sub Transform()
    For n = 0 To 500
        Ch2(n) = (Ch1(n) - 127) * (1 - Cos(n * pi / 500)) 'Hanning
    Next n
    For k = 1 To 500
        r = 0
        i = 0
        For j = 1 To 500
            r = r + Ch2(j) * Sin(k * j / 380)
            i = i + Ch2(j) * Cos(k * j / 380)
        Next j
        Ch1(k) = 1 / 100 * Sqr(r * r + i * i)
    Next k
End Sub
```

with the 5-V supply lead. With a voltage drop of approximately 0.7 V per diode, the supply voltage for the R8C/13 and display is reduced to 3.6 V (5 V - 1.4 V), which is within the allowed range for the display. The diodes can be fitted very easily by preparing a 'special' jumper for JP11 on the application board, with the two diodes wired in series between the contacts. Incidentally, we accidentally operated the display for a very short time at 5 V without any adverse effects. It thus appears to be able to survive such mistakes.

To enable the display to be driven in serial mode, you must bridge jumper JP3 on the back of the LCD circuit board with a drop of solder.

The signal lines required for serial data transmission are:

| DB7 = SID | to TXD0/P14 |
|------------|---|
| DB6 = SCLK | to CLK/P16 |
| /CS1B | to P1.3 |
| RS | to P1.7 |
| E | to ground |
| R/W | to ground |
| RST | to Reset or fitted with its own reset circuit |

The Reset line can be connected to the R8C/13 microcontroller Reset line. The display also has a white backlight LED that draws a current of 20 mA.

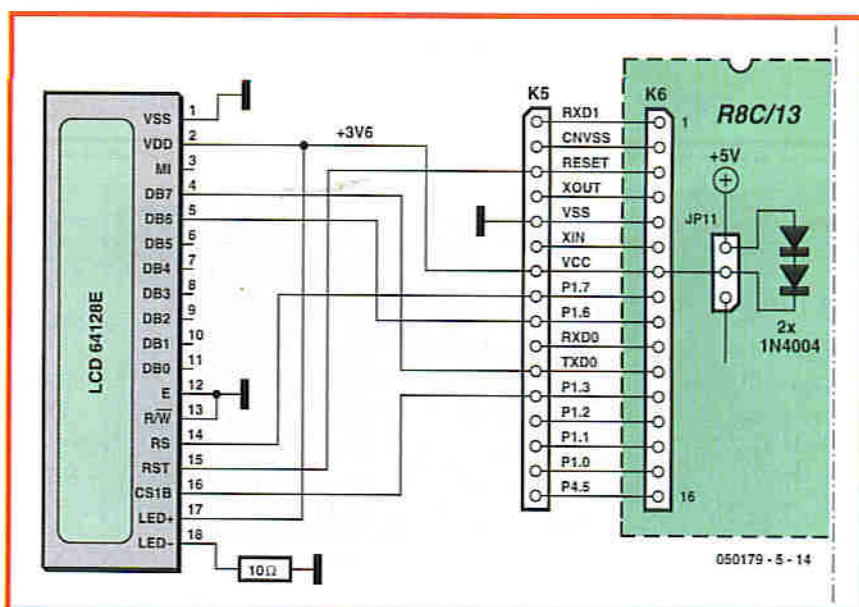


Figure 4. Display connection with reduced V_{CC}.

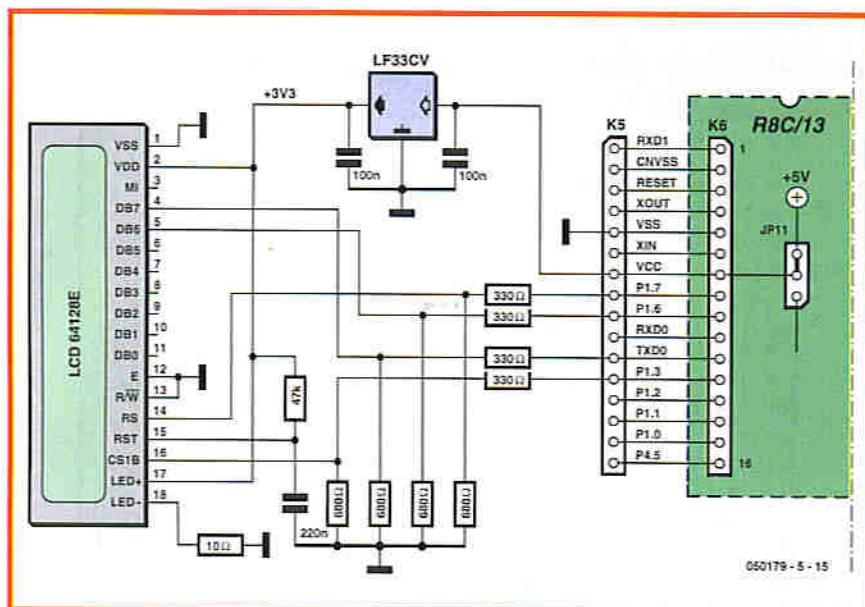


Figure 5. LCD connection with a 3.3-V voltage regulator.



Figure 6. Outputs from the sample project.

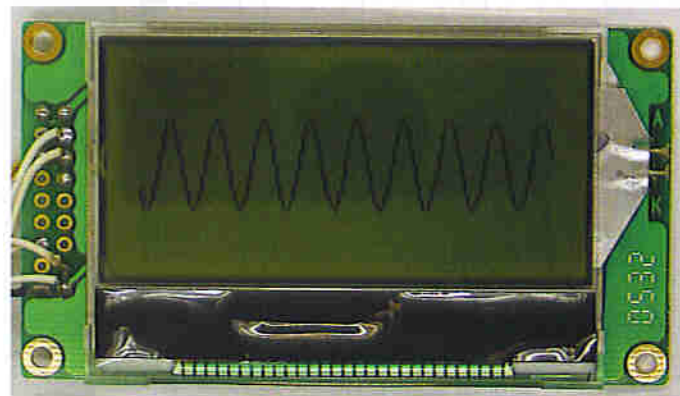


Figure 7. An oscillogram on the LCD.

The sample project for serial operation (LCD64128) implements two different serial drive methods: using the synchronous UART0 (SPI port) of the R8C/13 or using direct port instructions, which take more time. The project supports both options. The directive '#define SYNCUART0' selects fast SPI transmission with a clock rate of 1.6 MHz.

Unfortunately, the display RAM cannot be read back in serial mode, so a large 'shadow RAM' (1024 bytes) would normally be required. Here we use a trick in `ks0713.c` instead. It consists of storing only the most recently used bytes in a relatively small buffer. If a suitable sequence is chosen, characters and lines can be generated in this manner without overwriting previously generated elements.

The instruction '#define LCDSIZE 128' in file `ks0713.h` configures a buffer with 128 entries, which requires 384 bytes of memory. That value can be reduced if RAM space is tight. When you want to set a pixel, the function 'bitbuffer' first checks whether other pixels have already been set in the corresponding byte of the display before it sets the bit for the new pixel. However, the old bits will be lost if the routine encounters a location that could not be saved previously in memory.

A description of the details of the driver would exceed the scope of this article. However, the project code is carefully commented, so if need be you can figure out for yourself how it works. Here we limit ourselves to brief descriptions of the functions provided by the driver, which you can use to create your own projects.

```
lcdg_init();
    Initialises the display
lcdg_drawpixel(x,y,BLACK);
    sets a pixel at position (x, y)
lcdg_line(x1,y1,x2,y2,BLACK);
    draws a line from (x1, y1) to
    (x2, y2)
lcdg_circle(x,y,r,BLACK);
    draws a circle with origin (x, y)
    and radius r
lcdg_box(x1,y1,x2,y2,BLACK);
    draws a rectangle with corners
    (x1, y1) and (x2, y2)
ks0713_invert();
    inverts the entire content of the
    display
ks0713_normal();
    switches back to non-inverted
    display
ks0713_clrscr();
    clears the display
```



```
oprintf("%z%qText",x,y);
    writes a character string at
    location (x, y)
oprintf("%z%q%d",x,y,n);
    writes the integer n at location
    (x, y)
```

The `oprintf` function is a simplified version of the normal `printf` function in C. It can output integers as well as character strings. To keep the code size within limits, we omitted support for real numbers. The `char8.h` character set is supported with an 8×8 pixel matrix.

The sample project illustrates the capabilities of the display and generates the pixel graphic shown in **Figure 6**. It includes a line, a circle and a rectangle. Finally, a character string is output, including an incrementing number. The entire display is inverted after 20 passes through the routine and then restored to the normal state after another 20 passes. The example also demonstrates the limitations of the memory-saving graphics algorithm: a small portion of the drawn rectangle is erased by the superimposed text.

A mini oscilloscope

Now that all the necessary tools are ready, we can put together a small oscilloscope with an LC display. The data acquisition function is nearly the same as for the PC oscilloscope. However, in this case we only have to acquire 128 bytes. The entire LCD area is used to display the results (**Figure 7**).

As we need memory space to store the measurement data, the size of the auxiliary RAM for the display must be reduced. In this case, good results can

Listing 4

Measurement and display on the LCD ('LCD64128Scope' project)

```
void main(void)
{
    unsigned int adr;
    maxspeed();
    delay(10000);
    lcdg_init();
    while (1)
    {
        ;trigger();
        for (adr = 0; adr < 128; adr++)
        {
            ad_buf[adr] = (ad_in(6));
        }
        ks0713_clrscr();
        for (adr = 0; adr < 127; adr++)
        {
            lcdg_line(adr, 63-ad_buf[adr]/4, adr+1, 63-ad_buf[adr+1]/4,
BLACK);
        }
        delay(10000);
    }
}
```

Listing 5

Trigger function ('LCD64128Scope' project)

```
void trigger (void)
{
    int start;
    start = 0;
    while (p1_0 & !start)
    {
        while (ad_in(6) > ad_in(5));
        while (ad_in(6) < ad_in(5));
        start = 1;
    }
    while (p1_1 & !start)
    {
        while (ad_in(6) < ad_in(5));
        while (ad_in(6) > ad_in(5));
        start = 1;
    }
}
```

Serial interface timing

The program generates a 200-ms delay after sending the Start command. A shorter delay was initially configured here, since the actual measurement takes only 5 ms. After that, Readbyte receives the characters as fast as they arrive. A timeout value of 10 ms applies to the reception of individual bytes. Each byte, with its eight data bits, start bit and stop bit, takes 0.26 ms ($10 \times 1/38,400$ s), so there shouldn't be any problem. However, timing problems did occur with some relatively recent PCs and a few USB/RS232 adapters. It turned out that the data stream is temporarily stored in a buffer with a size of 64 bytes or so and then transmitted as a block in a USB frame. No problems occurred with the Prolific IC on the application board, but some recent-model PCs are no longer fitted with a 'normal' RS232 interface using a 16550 IC. Instead, they have a virtual COM interface that presumably also uses USB internally and exhibits exactly this buffer behaviour. That can cause time gaps in the received data stream, which in turn lead to timeouts. The 200-ms delay solves this problem by providing sufficient time for all the data to be received by the serial interface and stored in the receive buffer. After that, the VB program can read out the data at full speed.



Figure 8. Controls for the trigger function.

be obtained with '#define LCDSIZE 8'. The actual measurement process requires only a few lines of code (**Listing 4**), which makes for rapid display

of the results. The displayed curve consists of a large number of short line segments, each of which joins two sample points.

Triggering

A proper oscilloscope also requires a trigger function. The function 'trigger' provides the necessary capability in the code (**Listing 5**). An additional potentiometer is connected to AD_5 to set the trigger level. Two pushbutton switches are also needed (**Figure 8**). Triggering occurs on the negative edge if P1.0 is pulled high and on the positive edge if P1.1 is pulled high. If you use the LEDs on the application board, you get a trigger indication for free in the bargain – something you otherwise can only hope to find at the upper end of the price scale. Incidentally, you can adjust the trigger level of this oscilloscope during operation, just as with its analogue cousins, until a signal is displayed. If you can't manage to trigger on a signal, simply open the trigger switch and operate the 'scope in free-running mode.

Fourier analysis in the R8C/13

If you want to use mathematical functions such as sine and cosine with the R8C, you have to use a library (refer to our 'C Booklet' supplied with the March 2006 issue). The directive

Listing 6

Fourier analysis using the R8C/13 ('LCD641285pec' project)

```

while (1)
{
    for (adr = 0; adr < 256; adr++)
    {
        ad_buf[adr] = (ad_in(6));
    }
    for (adr = 0; adr < 256; adr++)
    {
        ad_buf[adr] = ((ad_buf[adr]-127)*(1 - cosf((float)adr * _PI / 128))/2+ 127);
    }
    ks0713_clrscr();
    c_old = 0;
    for (k = 0; k < 128; k++)
    {
        r = 0;
        i = 0;
        for (j = 0; j < 256; j++)
        {
            r = r + ((ad_buf[j]-127) * Sintab[(k * j / 4) & 255]) / 128;
            i = i + ((ad_buf[j]-127) * Sintab[(k * j / 4 + 64) & 255]) / 128;
        }
        r = (int)sqrtf(((float)r*(float)r+(float)i*(float)i)) ;
        c = r/ 200 ;
        //c= ad_buf[k]/4;
        lcdg_line(k, 63-c_old, k+1,63-c, BLACK);
        c_old = c;
    }
    delay(10000);
}
}

```


#include "mathf.h" allows you to use functions such as `sinf`, `cosf` and `sqrtf` for floating-point ('float') values, which require less memory than the usual functions for the 'double' format. However, they take up considerably more space in ROM. In its default configuration, the compiler is limited to a maximum program size of 8 KB, so the start of ROM must be moved down from 0e000H to 0c800H. That leaves enough room for the firmware of the KD30 debugger. Line 609 of file 'Sect30.inc' must be modified accordingly. Incidentally, the entire LCD64128Spec project generates a code volume of 10,950 bytes.

```
.section    rom_NE,ROMDATA
.org       0c800H
```

The compiler directive #include "mathf.h" is important here. Although the source code will compile without an error message if it is missing, the mathematical functions used in the code will not work properly. It's also important to pay attention to upper-case and lower-case characters, because only floating-point values can be passed to the functions. The conversion function 'float(adr)' converts the integer variable 'adr' into a real number in floating-point format (Listing 6).

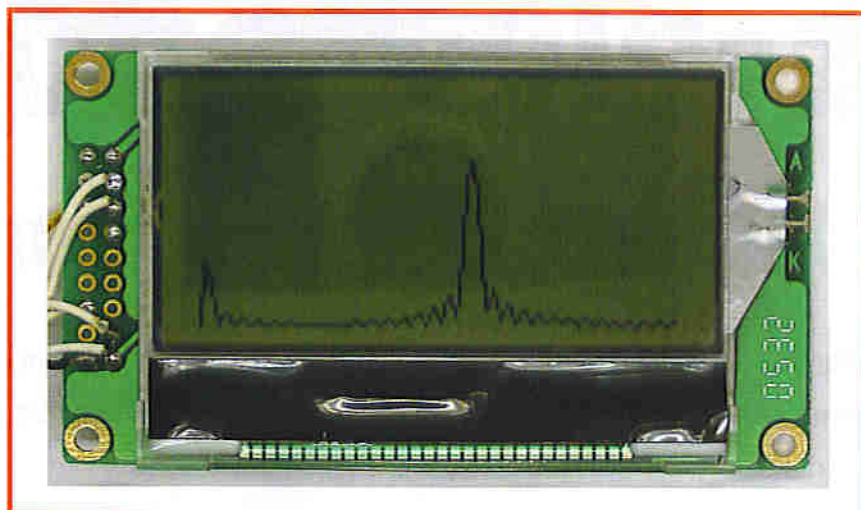


Figure 9. A Fourier analysis without the Hann window.

The sample project shows that working with C for the R8C/13 is just as easy as using Visual Basic for the PC. However, due to time constraints the actual computation loop for the Fourier transform has to manage without the `sinf` function, because 65,536 sine calculations and multiplications would simply take too long. A pre-calculated sine lookup table is used instead. That

reduces the computational effort to 65,536 multiplications in 16-bit format, which the R8C manages without batting an eye. By contrast, the 256 `cosf` calls for the Hann window and 128 `sqrtf` calls for the vector addition do not cause any objectionable delay. The full screen display is generated in a fraction of a second.

(050179-5)

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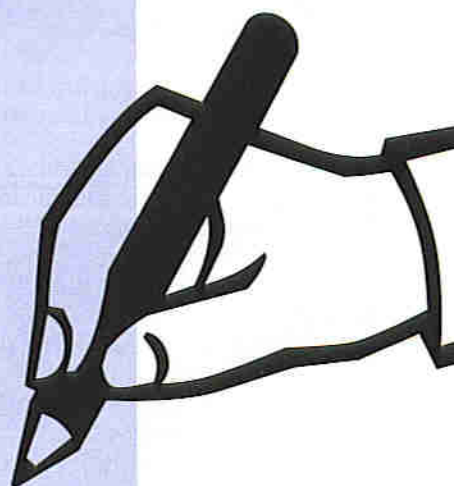
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E-blocks for Protot

Design an E-blocks controlled PSU

Many readers have asked how they can make their own E-blocks. This month we take a look at some options on making your own prototype E-blocks and give you some suggestions for E-blocks that we would like to see.

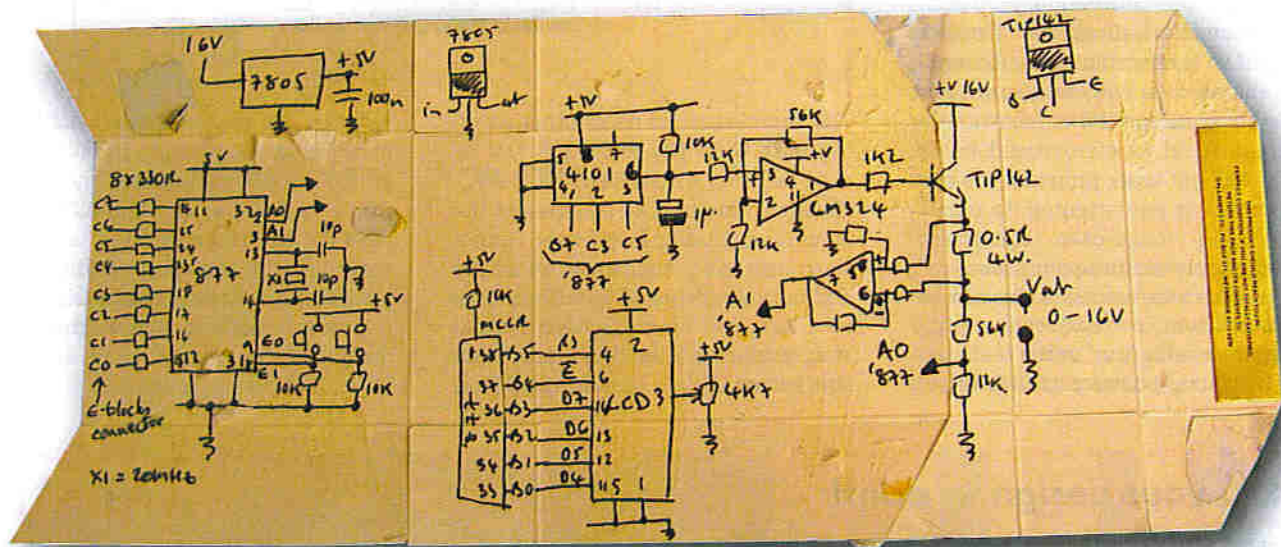


Figure 1. Our cigarette packet plan.

The first step to making an E-block is to get some hardware up and running. Before you do that you need some kind of plan for what you want to make. Usually with electronics this means you have to draw up a circuit diagram. To make your initial design you will need to draw on information from datasheets: the datasheets on the development equipment you are using and the datasheets on the electronic components you plan to use. Your schematic can take many forms – from a Computer Aided Design (CAD) schematic, to a sketch on the back of a cigarette packet. For the sake of this article we have gone for the 'cigarette packet' approach that you can see here. On the cigarette packet in **Figure 1** you can see my ideas for a simple benchtop instrument containing a basic E-blocks logic analyser and a voltage-variable power supply. As well

as being a useful instrument, I am hoping this will help me learn a little more about analogue electronics.

At this stage of a project I like to make sure I have all the information I am likely to need: which pin numbers on the ICs correspond to each signal lines, pinout of the transistors, etc. You can see that even on this simple diagram there is quite a lot of information.

My plan

At the heart of the system is a 16F877 40-pin PICmicro with 20-MHz crystal oscillator and two push-to-make switches on E0 and E1. A two-line 16-character alphanumeric LC display is connected to port B of the PICmicro. Port C of the device is connected – via 330-ohm resistors – to an E-blocks port (not shown) on the left of diagram. I plan to use the first line of the LCD display.

play to show me the status of the lines on Port C in both binary and hex formats. Later I might also use this for monitoring I²C or SPI bus commands, which is why I chose port C as it is internally connected to the PIC USART (universal serial asynchronous receiver/transmitter). A good old 7805 regulator will create 5 V for the circuit from a spare 16-V 'rat's-tail' power supply I had in the drawer. I have used an SPI-bus 256-step potentiometer – the MCP4101 from Microchip — and connected it to C3 (clock), C5 (data) and B7 (chip select) of the '877. The 10-k Ω 4101 is the bottom part of a potential divider, with a 10-k Ω resistor to +5 V. This produces an output from 0 to 2.5 V in 256 steps. This signal is amplified by a LM324 opamp powered off the 16-V input to produce an output between 0 and (hopefully) 16 V. A simple TIP142 NPN Darlington transistor – effectively

Typing Systems

John Dobson

an emitter follower — then provides the power supply output. The emitter of the Darlington is fed to a $0.5\text{-}\Omega$ resistor and then to the screw terminal output connector. A differential amplifier will amplify the voltage across the $0.5\text{-}\Omega$ resistor, allowing me to make a display of the current output. This will feed into pin A1 of the '877. The output voltage is also divided down by potential divider chain to produce a signal between 0 and 3 V which is directly proportional to V_{out} . This is connected to pin A0 of the '877. So I can have the software calculate and display both the output voltage and current of the power supply. I plan to produce all of the code for this using Flowcode.

Getting started

My first aim is 'proof of concept' and 'technical risk': I want to know if the idea is likely to work and test the core components: particularly the linear potentiometer which I have never used before. We are going to base our initial prototype on the E-blocks system, as we have a PICmicro programmer, displays, switches, which all connect together very quickly. All we need to do is prototype the parts of the circuit that we don't have: the MCP41010 design, the opamps. I won't bother to prototype the output stage just yet as I am more confident about that part of the design. It makes sense to me to get the 41010 working first as I have never used it and to test the fundamental theory of our design and get the values of the resistors in the op-amps right. The MCP41010 and the LM324 can be seen in close-up on **Figure 2**, and you can see the initial prototyping E-blocks system in **Figure 3**.

In **Figure 3** you can see we have an E-blocks PICmicro Multiprogrammer with an LCD display on port B, some switches on port D, and port A and C feeding onto the prototype board containing our 41010 and LM324 circuit. Once the circuit diagram was established this only took around 15 minutes to construct.

Here is a hint: in **Figure 2** you can see that we are using a pack of small multi-strand leads with rugged gold end terminals to make the connections

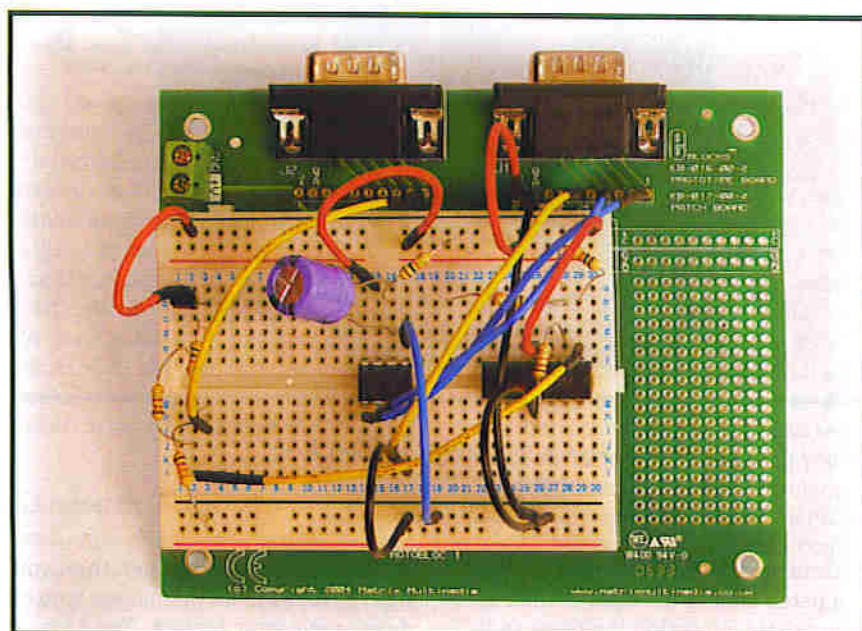


Figure 2. The MCP4101 and the LM324 happy together on a prototype board.

on the prototype board. You can use single core wire for this quite adequately, but if you are going to do this frequently then the proper leads are worth investing in: the single core wires have a tendency to snap off inside your Protoblock, and they are slightly too large for inserting into

turned-pin sockets which are almost universally used for prototyping. Note also that on the prototype board shown there are

- two E-blocks D-type connectors;
- two terminal screw connectors for power and ground;
- two single inline 9-way turned pin

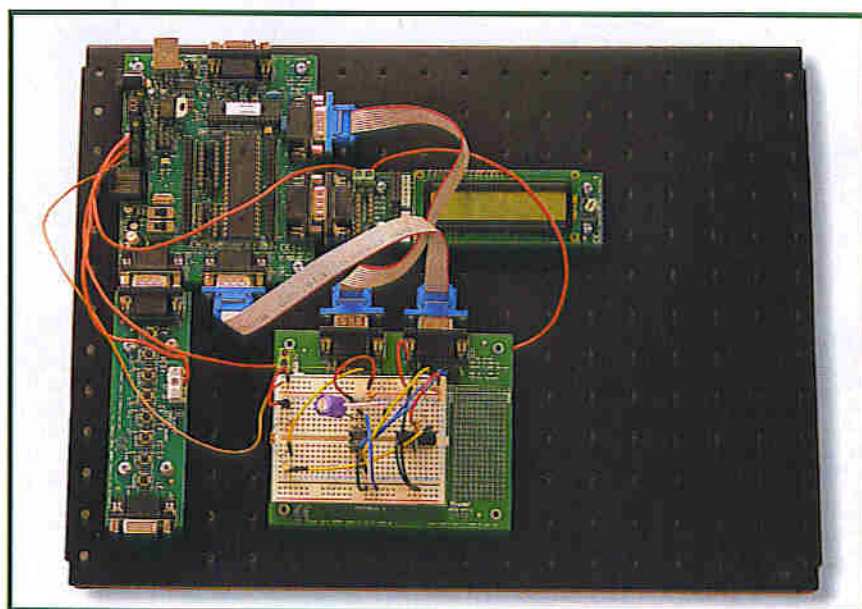


Figure 3. The E-blocks prototyping system.

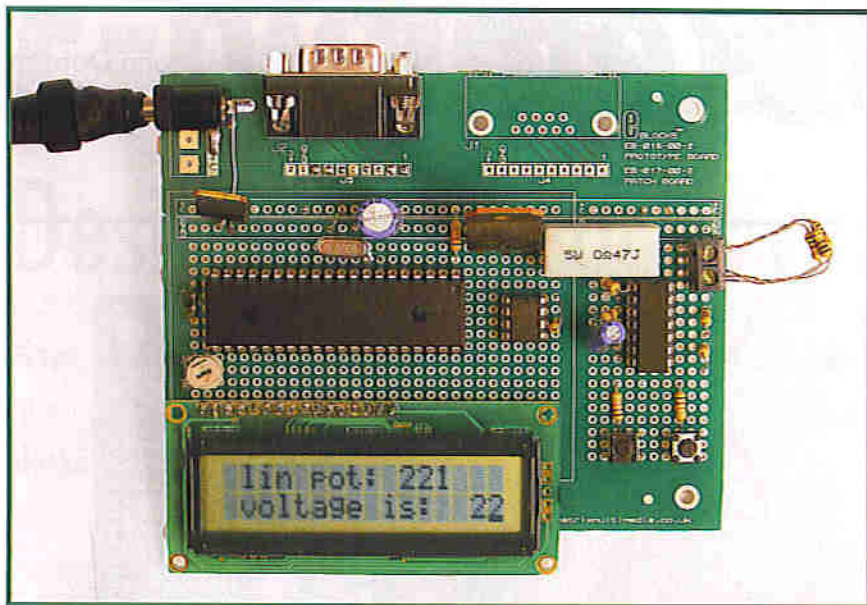


Figure 4. The final design on a patch board.

sockets for both E-blocks ports;

- a patch area to the right of the Protoblock for connecting the more awkward components that won't fit onto your Protoblock, these include potentiometers and surface mounted components (SMDs).

Patch boarding

The problem with the Protoboard approach is that it is only temporary —

once your design is proven then you need to find a more permanent way of developing your project. You have a number of choices here:

- develop a custom printed circuit board (the best method, but time consuming and expensive);
- use stripboard a.k.a. veroboard or perfboard (yeuch!);
- use what we call a patch board.

Patch boards simply consist of a bare

circuit board with a large number of plated through holes onto which you solder your final circuit. Once you are confident of your design, you can simply go ahead and solder the components on and wire them up — if you do make a mistake then it is easy enough to remove the components. Note that some people use patch boards for the first prototype, but it does take longer to correct mistakes. The great advantage of the patch board system is that, as all the components are soldered onto the board, it is more rugged and essentially makes a more permanent E-block component.

In **Figure 4** you can see the final design on an E-blocks patch board. This has an E-blocks connector on the top and all the components mounted onto the board and soldered in place. When it comes to wiring, you also have some choices: you can use coloured single-core wire, which provides a strong and easily traceable circuit, but can get messy when you have lots of connections (note on this design there are around 50 wires). I prefer another approach which is much, much faster: if you look at **Figure 5** you can see that I have used what is called 'wiring pencil wire'. This thin wire has a layer of polyurethane insulating coating that burns away with a soldering iron to reveal the copper wire beneath. To use it you just apply the soldering iron for a second or so and then solder it to the appropriate component pin. I don't

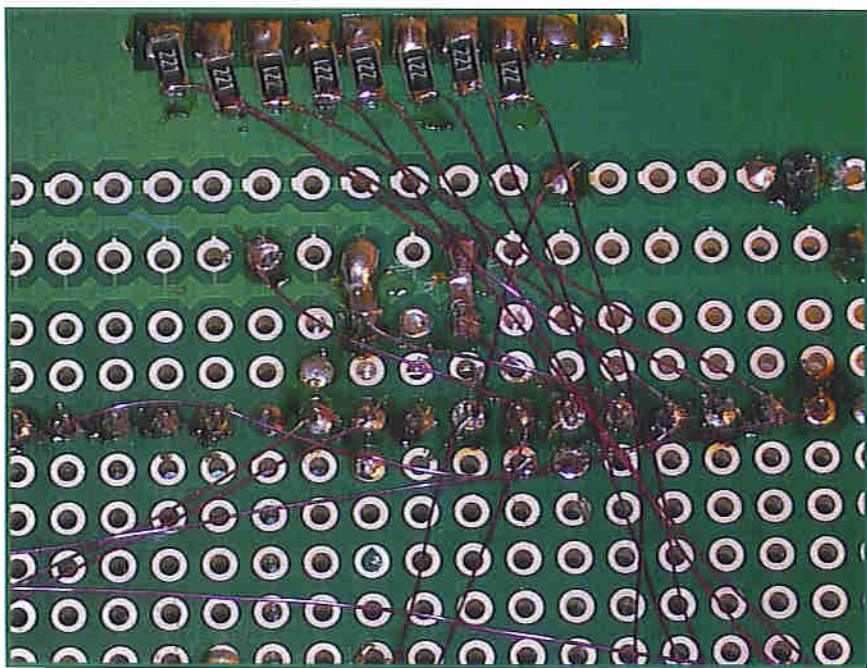


Figure 5. Close up of the bottom of the patch board showing wiring and SMD components.

Earlier in this series

Electronic Building Blocks,
November 2005.

E-blocks and Flowcode,
December 2005.

E-blocks in Cyberspace,
January 2006.

E-blocks - now you CAN,
February 2006.

E-blocks Making Waves,
March 2006.

E-blocks Making Waves at C,
April 2006.

Articles may be downloaded individually from our website.

For a complete overview of available E-blocks visit the relevant SHOP pages at

www.elektor-electronics.co.uk

Call for Papers

Here are a few suggestions for E-blocks projects we would like to see:

DMX • RFID • Zigbee • Joystick • Camera • SRD RF transceiver • Compass • Real-time clock •
FPAA interface • Colour sensor • 8051 • Z80 • PC E-block.

Readers are invited to submit outlines and detailed propositions for any of the above projects.

know of a faster way of making a circuit and the results are surprisingly rugged. In Figure 5 you can see that I have also used some surface-mounted components on the bottom side of the patch board.

Design summary

The design itself seems to work fairly well. The collector-emitter drop on the Darlington was more than I expected and I ended up with an output range of around 0 to 12 V rather than the desired 0 to 16 V. I tested the design with a resistive load (ah the aroma of burning resistors) and drew around 350 mA. I did not get round to develop-

ing the current monitor circuit and software, and my voltage algorithm in Flowcode only gave an integer read out. Room for improvement in the programming department!

I was impressed by the ease of use of the Microchip MCP4101 device and will certainly use it again. If you are going to use it make sure you have the most recent SPI components for Flowcode installed. An article on SPI was published in last month's *Elektor Electronics*.

Conclusion

From this brief article you have hopefully seen the steps you need to take to make your own E-blocks board, and

also how you can take a project from the initial prototyping through to a finished item.

We are always looking for new project ideas for E-blocks and we have a large number of new boards coming in the next few months (including Bluetooth, Bluetooth CODEC, SD/MMC card reader, motors, LIN, PS2/VGA, optoisolator, USB/RS232, MP3, GPS, and relay). However, there are a several other functions that we would like to see in E-blocks format listed above. If you are interested in developing a project for these – including the code for a PICmicro based in C – then please contact the Editor.

(065041-1)

CONSTRUCTION GUIDELINES

Elektor Electronics (Publishing) does not provide parts and components other than PCBs, and preprogrammed ICs (not necessarily for all projects). Components are usually available from a number of retailers – see the adverts in the magazine. Selected projects are supplied as kits.

Large and small values of components are indicated by means of one of the following prefixes:

| | |
|----------------------|---------------------------|
| E (exa) = 10^{18} | a (atto) = 10^{-18} |
| P (peta) = 10^{15} | f (femto) = 10^{-15} |
| T (tera) = 10^{12} | p (pico) = 10^{-12} |
| G (giga) = 10^9 | n (nano) = 10^{-9} |
| M (mega) = 10^6 | μ (micro) = 10^{-6} |
| k (kilo) = 10^3 | m (milli) = 10^{-3} |
| h (hecto) = 10^2 | c (centi) = 10^{-2} |
| da (deca) = 10^1 | d (deci) = 10^{-1} |

In some circuit diagrams, to avoid confusion, the value of components is given by substituting the relevant prefix for the decimal point.

For example, $3k9 = 3.9 k\Omega$ $4\mu F7 = 4.7 \mu F$

Unless otherwise indicated, the tolerance of resistors is $\pm 5\%$ and their rating is $\frac{1}{8}$ – $\frac{1}{2}$ watt. The working voltage of capacitors is ≥ 50 V.

In populating a PCB, always start with the smallest passive components, that is, wire bridges, resistors and small capacitors; and then IC sockets, relays, electrolytic and other large capacitors, and connectors. Vulnerable semiconductors and ICs should be done last.

Soldering. Use a 15–30 W soldering iron with a fine tip and good quality solder tin. Insert the terminals of components in the board, bend them slightly, cut them short, and solder: wait 1–2 seconds for the tin to flow smoothly and remove the iron. Do not overheat, particularly when soldering ICs and semiconductors. Unsoldering is best done with a suction iron or special unsoldering braid.

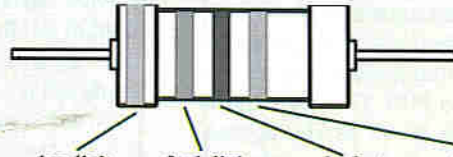
Faultfinding. If the circuit does not work, carefully compare the populated board with the published component layout and parts list. Are all the com-

ponents in the correct position? Has correct polarity been observed? Have the powerlines been reversed? Are all solder joints sound? Have any wire bridges been forgotten?

If voltage levels have been given on the circuit diagram, do those measured on the board match them – note that deviations up to $\pm 10\%$ from the specified values are acceptable.

Possible corrections to published projects are published from time to time in this magazine. Also, our online Forum often contains useful comments/additions to the published projects.

The value of a resistor is indicated by a colour code as follows.



| color | 1st digit | 2nd digit | mult. factor | tolerance |
|--------|-----------|-----------|------------------|-------------|
| black | – | 0 | – | – |
| brown | 1 | 1 | $\times 10^1$ | $\pm 1\%$ |
| red | 2 | 2 | $\times 10^2$ | $\pm 2\%$ |
| orange | 3 | 3 | $\times 10^3$ | – |
| yellow | 4 | 4 | $\times 10^4$ | – |
| green | 5 | 5 | $\times 10^5$ | $\pm 0.5\%$ |
| blue | 6 | 6 | $\times 10^6$ | – |
| violet | 7 | 7 | – | – |
| grey | 8 | 8 | – | – |
| white | 9 | 9 | – | – |
| gold | – | – | $\times 10^{-1}$ | $\pm 5\%$ |
| silver | – | – | $\times 10^{-2}$ | $\pm 10\%$ |
| none | – | – | – | $\pm 20\%$ |

Examples:
brown-red-brown-gold = 120Ω , 5%
yellow-violet-orange-gold = $47 k\Omega$, 5%

UV LED Light

More efficient PCB exposure

Reinhardt Weber

Commercial PCB exposure light boxes usually employ gas discharge tubes as an ultraviolet (UV) light source, these devices are however bulky, fragile and costly. Incandescent lamps are not a good alternative; they produce a lot of heat and relatively little UV. An interesting development boasting high efficiency and excellent reliability is the recently introduced UV LED.

This design will be welcomed by anyone considering homebrew PCB production, it uses the L-7113UVC type UV LED from the 'Super Bright LED Lamps' range by Kingbright to build a UV light box. The emission wavelength of this LED is precisely 400 nm, ideal for transferring a mask pattern to the photo-resist layer of coated PCBs. The maximum LED forward current is quoted as 30 mA, producing a voltage drop of 4.2 V.

The entire light source is made up of 24 diodes arranged in a grid pattern to ensure even illumination across the Eurocard sized PCB. The beam angle for this LED is given as 20 degrees. Beam edges are defined as points in the radiation pattern where the luminous intensity has fallen 50 % compared to its peak at the centre of the beam. The LED grid spacing is chosen to ensure that the overlapping light cones produce an even distribution of light over the complete area of exposed PCB.

Figure 1 gives the exposure time as a

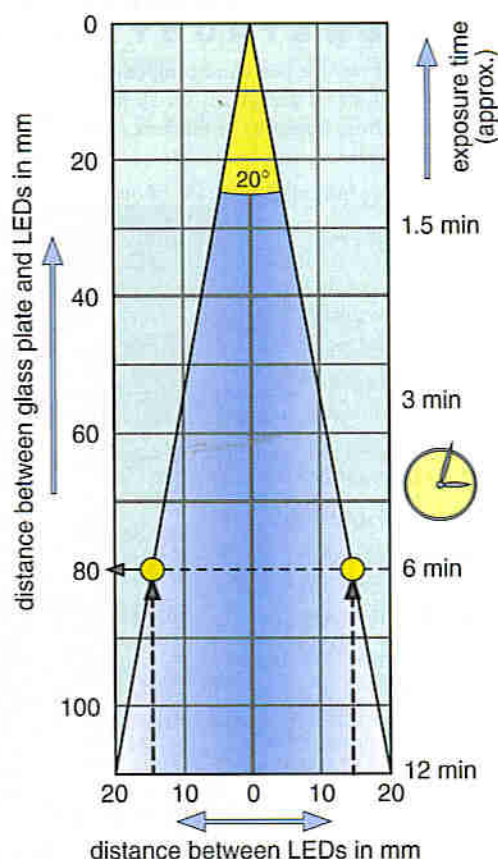


Figure 1.

Correlation of LED spacing, distance to the glass plate and exposure time.

060029 - 11

Box



function of LED spacing and distance from the LEDs to the glass platen. There will be some variance between PCB materials supplied by different manufacturers and to some extent the age of the material.

Eurocard illumination

Placing the LEDs closer together allows a shorter distance between the LEDs and the glass platen. This would increase the UV intensity and reduce the PCB exposure time but at the expense of more LEDs, as ever we run into the speed versus cost trade off. The LEDs in this design are arranged in a grid on a Eurocard sized PCB with a spacing of approximately 31 mm. The total number of UV LEDs required for this 100 mm x 160 mm card is 24 (Figure 2). At a distance of about 80 mm between the LEDs and the glass platen the light exposure time for a PCB was found to be around six minutes. The optimal distance between the LEDs and glass platen to give an even light distribution can be determined

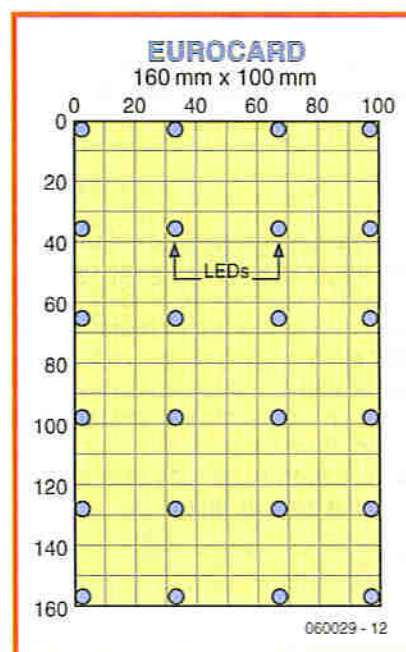
empirically; put on a pair of UV protection glasses and place a sheet of white paper over the glass platen, move it away from the LEDs until the individual pools of light overlap to form a uniform area of illumination on the sheet. The distance can be increased to cover a greater area but the PCB mask exposure time will need to be increased correspondingly.

Circuits don't get much simpler

The electrical assembly work for this design involves little more than soldering the LEDs to suitable series resistors. The LEDs are wired as 12 pairs, each with a single 120 Ω series resistor connected to the 12 V input (Figure 3). Each pair draws about 25 mA so the 12 V mains adapter must be capable of supplying a total of around 300 mA. The reverse breakdown volt-

age of an LED is relatively low compared to a silicon diode so D1 protects the entire circuit against input voltage polarity reversal. For simplicity and speed the complete circuit can be built on a sheet of perforated prototyping board. The author

Figure 2. LED layout on the Eurocard sized PCB.



has also produced a Eurocard sized PCB for the circuit (**Figure 2** and **Figure 3**) and also a half size board containing 12 LEDs. Both of the layouts can be downloaded from www.elektor-electronics.co.uk free of charge, the file number is 060029-1.zip (see articles listed for this month May 2006).

Construction

Before any components are mounted on the board it is necessary to apply some form of reflective layer to the board surface. This can be self adhesive white plastic film or a few layers of white spray paint, a particularly good finish can be achieved with a layer of metallic silver followed by a layer of clear lacquer. The light-scattering property of this finish helps to produce good, even illumination across the board.

The PCB carrying the LEDs can now be fitted (glue or screw) into the base of a suitably sized container or enclosure. Leads carrying power to the cir-



Figure 4. This warning symbol can be used on the unit. UV protection glasses must be worn; eyes can be damaged by the high intensity UV.

It is especially important not to look directly into the UV beam!

cuit are fed from the back of the PCB through a hole in the casing or via a suitable connector to a 12 V mains adapter. The unit is now complete and only requires the glass platen to be fitted or glued to the container. Finally don't be tempted to cut corners with the PCB material, in the long run it always pays to use the best quality material you can afford.

(060029-1)

Links

www.kingbright.com
www.rs-components.co.uk
www.reichelt.de

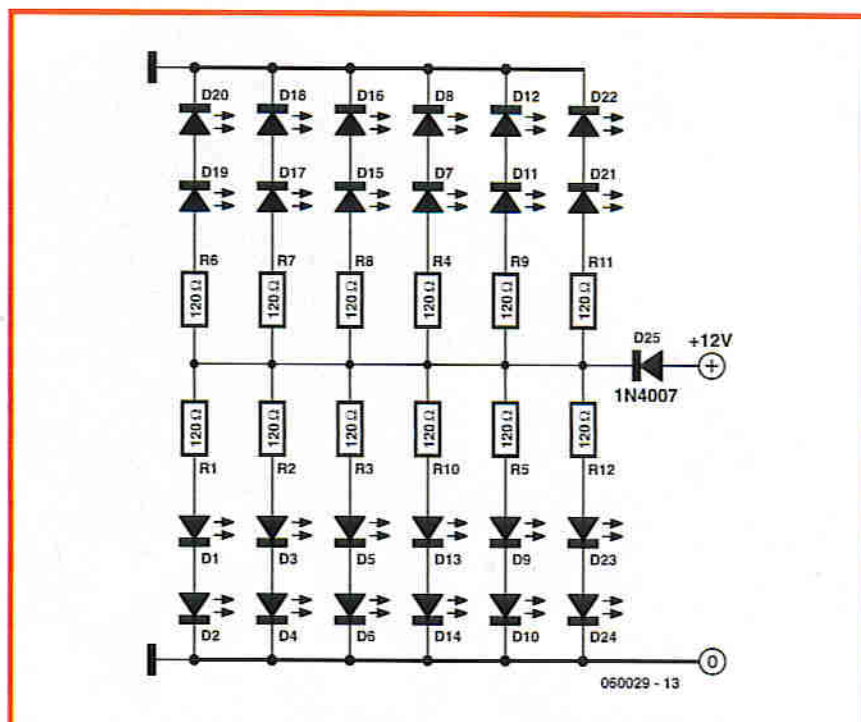
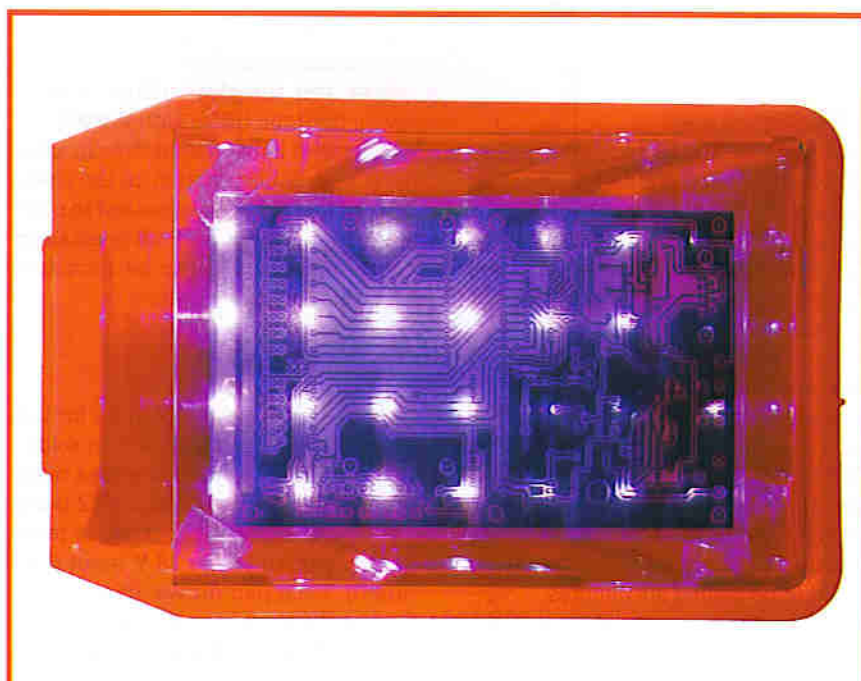


Figure 3. The circuit uses 24 LEDs. A free PCB layout can be downloaded from www.elektor-electronics.co.uk.

Materials and suggested sources:

12 pcs. 120-Ω resistor
 1 pc. diode 1N4001
 24 pcs. UV-LED, Kingbright L-7113UVC (RS Components Stock No 507-4034)
 1 pc. connection cable for mains adapter

1 pc. components storage cabinet with drawers, approx. size 140 x 220 x 120 mm (W x L x H)
 1 pc. glass platen, cut to size, or glass cover of frameless picture holder.
 White or metallic silver self-adhesive foil (or clear lacquer, see text)



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Example screenshots:

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Base Emit Coll
Current gain
H_{FE}=117
Test current
I_C=2.50mA
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V_{BE}=0.71V
Test current
I_S=4.50µA
Leakage current
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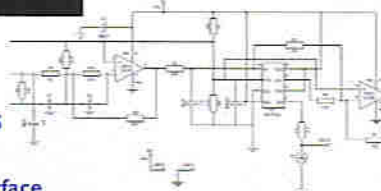
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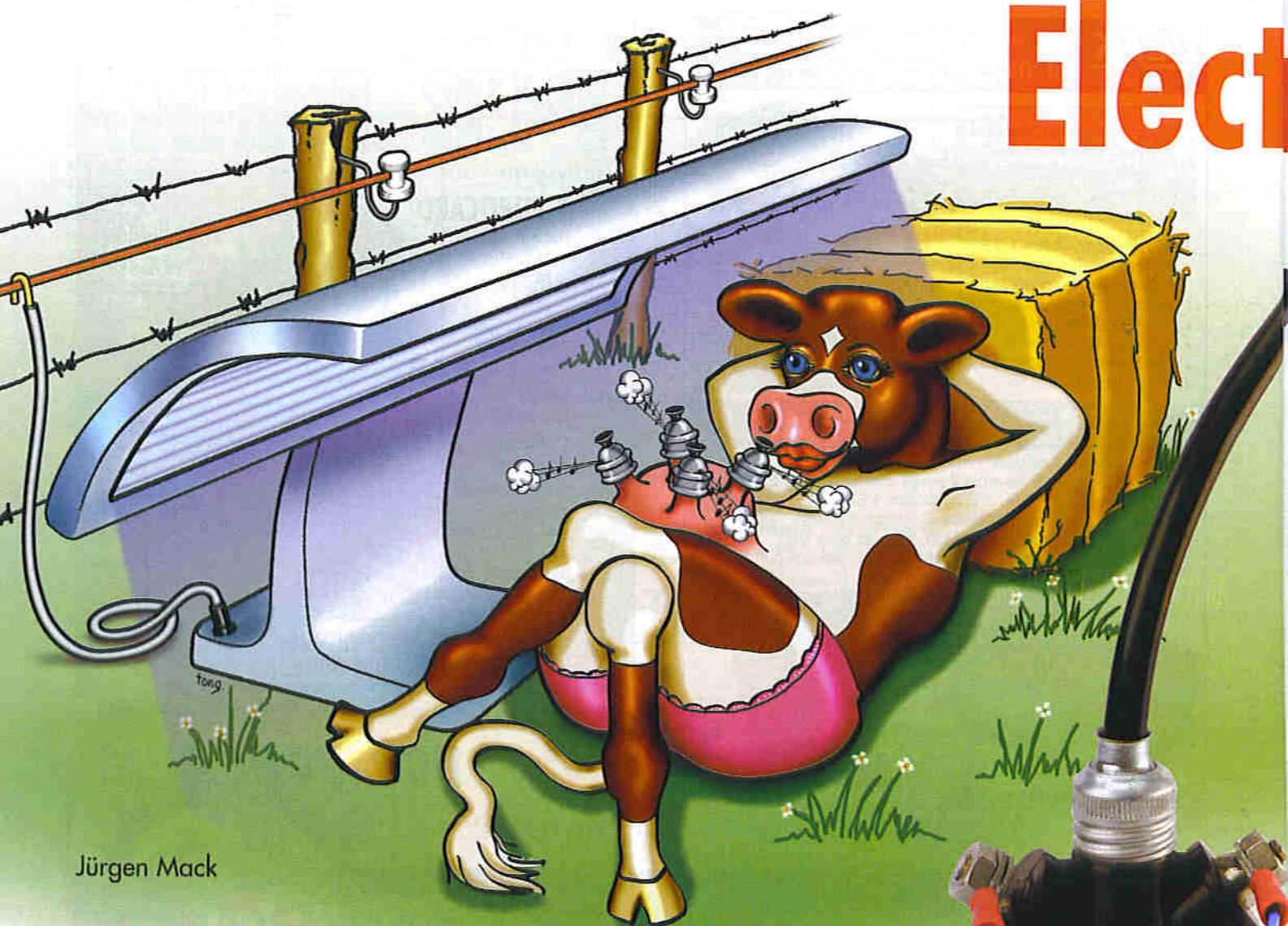
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Are you bothered by stray cats and dogs prowling and digging in your garden? Or does your own pet require strong persuasion to stay within a restricted area? This electric fence generator may well be the answer to your problems. A simple generator built around a 555 timer and an old ignition coil are sufficient to build a suitable circuit at a small outlay.



Electric Fence Energizer

Those of you who have been with us since the mid-1970s may recall the 'disposable' circuits we used to print on the address label used to get the mag to subscribers. One of the more illustrious designs from that dim past was an electrified wire circuit. Now, more than 35 years on, we present its successor — an old idea but using a fresh approach.

Of course, electric fence units can be purchased commercially and these will typically include a water-resistant enclosure. However, honouring 'home construction is more fun' we thought it would be nice to build such a unit ourselves.

A small circuit

As shown by the schematic in **Figure 1**, the circuit proposed here does not require much in the way of components. The one part that may strike you as less usual is the ignition coil. If you find a new coil rather expensive, visit the local car breakers for one salvaged from a vehicle and you'll notice the price difference. The remainder of the components are fairly standard. The circuit diagram requires very little comment. The circuit is built around

the timer IC type 555 (IC1), which is configured here as an oscillator with adjustable pulse/pause ratio.

Since in this case we wish to combine a very short 'on' time with a long 'off' time, two diodes, D2 and D3, are included in the frequency determining network. Using slide switch S1 you can select between three pulse ratios, this is effectively achieved by connecting to different taps in potential divider R1-R5.

The output of the 555 drives a power MOSFET (T1), which in turn connects the ignition coil primary to ground during the pulse 'on' time. This causes a strong voltage surge induced into the secondary, which is connected to the fence wire.

Components D6, C7 and C8 ensure that the timer IC can operate 'on its own' for a short time. This has to do with the fact that an (almost) drained battery may result in the IC being reset, which in turn upsets the pause between the discharge pulses. These would then follow at a too fast rate. To prevent an unwieldy value for C7, we used a CMOS TLC555 instead of the plain vanilla, bipolar NE555. Finally, a voltage indicator has been added with D1, R7 and D5.

Quick specs

- Discharge energy selectable between 250 mJ, 400 mJ and 450 mJ.
- Low current consumption: 25 mA, 70 mA or 150 mA depending on discharge energy selection.
- Long lasting: 50, 20 or 8 days depending on discharge energy (using a 45 Ah battery and 2/3 discharge).
- 1.5 seconds between pulses (easily adaptable with R5).
- Pulse duration selectable between 16.5 ms, 24 ms and 31 ms.
- Current consumption of control board: max. 1.6 mA.

Further reading

www.foothill.net/~ringram/energizer.htm

Building it

Figure 2 shows the copper track layout and component mounting plan of the PCB designed for this little circuit. Construction will be mostly plain sailing, although we should mention that

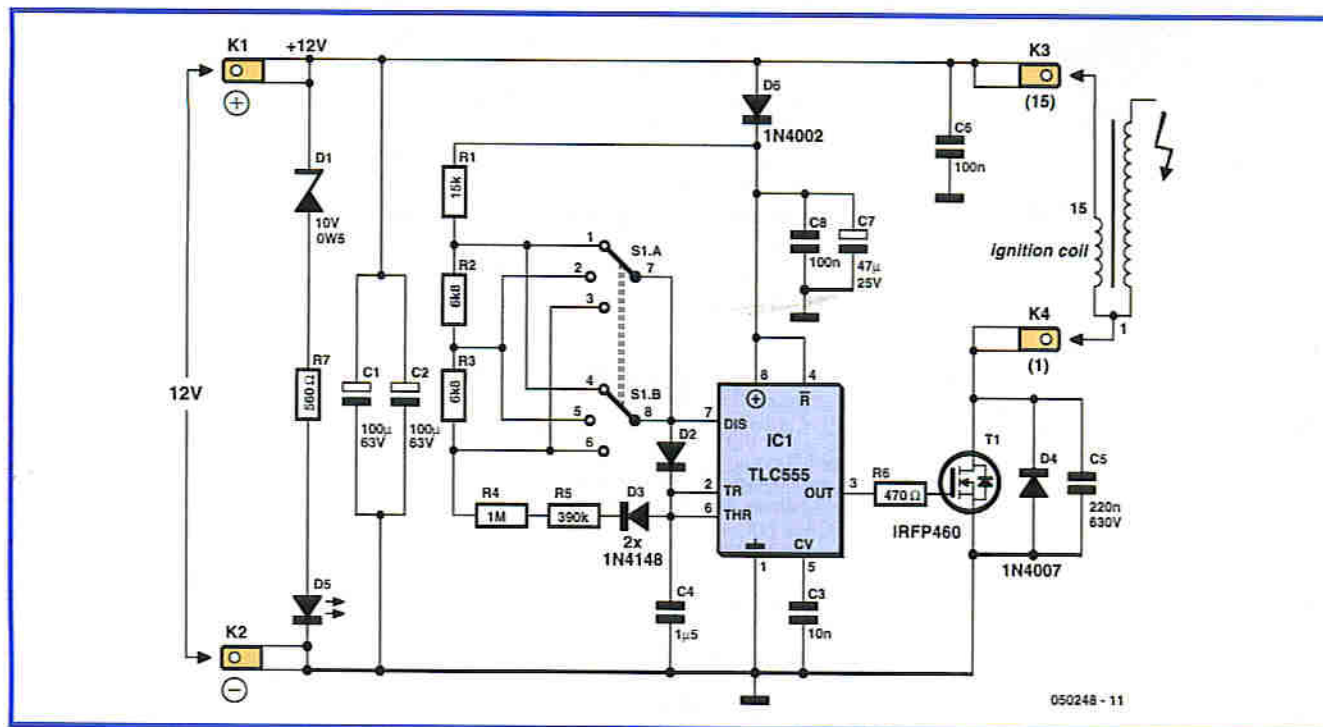


Figure 1. Here a 555 is configured as an astable multivibrator.

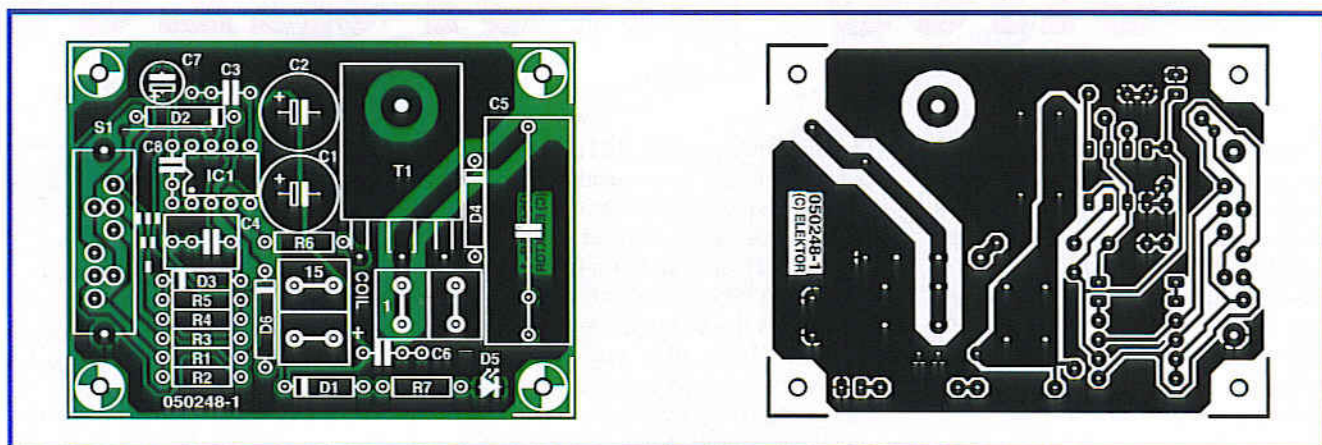


Figure 2. The PCB has remained nicely compact. The coil is much larger!

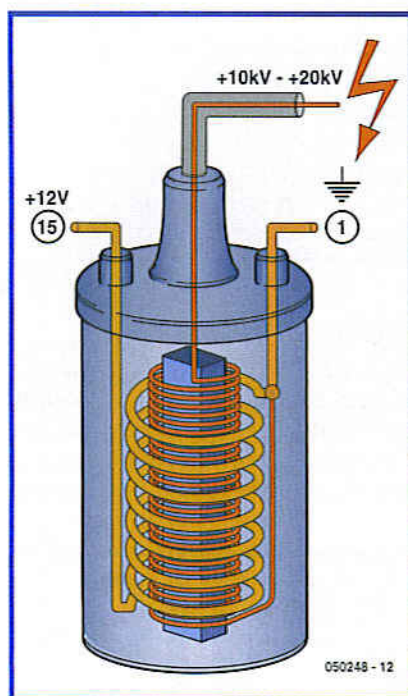


Figure 3. For clarity's sake we have pictured the construction of a vehicle ignition coil. The primary and the secondary share a common ground terminal.

the wire link next to D2 must not be forgotten.

A few remarks should also be given about some of the other components: For the frequency determining capacitor C4 we used a Siemens MKT type because of its low leakage and longer life expectancy compared with an electrolytic cap. The value of R7 may be changed depending on how brightly you want to see the LED light.

If C5 turns out to 'play hard to get' (locally) then consider using an alternative dimensioning. R1 then becomes 8k2; R2 and R3 4k7 and C5 470 nF / 630 VDC.

A possible alternative to the MOSFET is, for example, the 20N60. Incidentally, the MOSFET is not mounted directly onto the PCB, but at a few mm above the PCB surface using a bolt and two nuts. This mounting method helps the device stay reasonably cool.

If the time between pulses is too long, R5 may be replaced by a wire link.

The ignition coil (Figure 3) should preferably be one from an electronic

ignition system for 12-V cars. The type we happened to use had a primary resistance of about 0.7 Ω and a self-inductance of 5 mH. To protect the coil against faults in the circuit we strongly recommend using an in-line fuse. After all, if the 555 fails or goes haywire from some reason or other, the ignition coil primary forms a virtual short-circuit on the battery and a very high current will start to flow, eventually causing the coil to be destroyed or, worse, causing a fire. To increase the reliability of the circuit, it is best to solder the IC directly onto the circuit board, yes that's without a socket. IC socket pins are subject to oxidation in the typical environment the circuit will be used in (outside, in a garden or meadow). For the same reasons of reliability, we're using two paralleled switch contacts instead of just one, reducing the risks of a bad contact disturbing your night rest. If it is desired to operate the switch with the circuit in an enclosure, you may find it useful to mount it at the solder side — just look at the height of C5 and the Fast-on (spade) connectors.

(050248-1)

COMPONENTS LIST

Resistors

- R1 = 15k Ω
- R2, R3 = 6k Ω 8
- R4 = 1M Ω
- R5 = 390k Ω
- R6 = 470 Ω
- R7 = 560 Ω

Capacitors

- C1, C2 = 100 μ F 63V radial

- C3 = 10nF
- C4 = 1 μ F5 MKT, lead pitch 5mm or 7.5mm
- C5 = 220nF 630V MKT, lead pitch 22.5 or 27.5mm, size 11x30 mm
- C6, C8 = 100nF
- C7 = 47 μ F 25V radial

Semiconductors

- D1 = zener diode 10V 0.5W
- D2, D3 = 1N4148
- D4 = 1N4007
- D5 = LED, low-current
- D6 = 1N4002
- T1 = IRFP460PBF (500 V/20 A,

- TO247AC), e.g., Digi-Key IRFP460PBF-ND
- IC1 = TLC555CP (do not use NE555!)

Miscellaneous

- K1-K4 = Fast-on (spade) connector, vertical, 2-way PCB mount
- S1 = slide switch, PCB mount, 3 x changeover (2 poles, 3 positions), e.g., Conrad Electronics 708097-62
- In-line fuse 4A T (slow) with holder
- 12-V ignition coil (w. length of spark plug cable)
- 1 wire link (next to D2)
- PCB, ref. 050248-1 from The PCBShop

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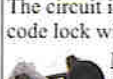
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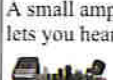
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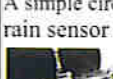
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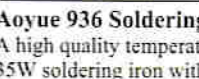
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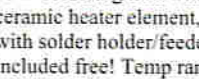
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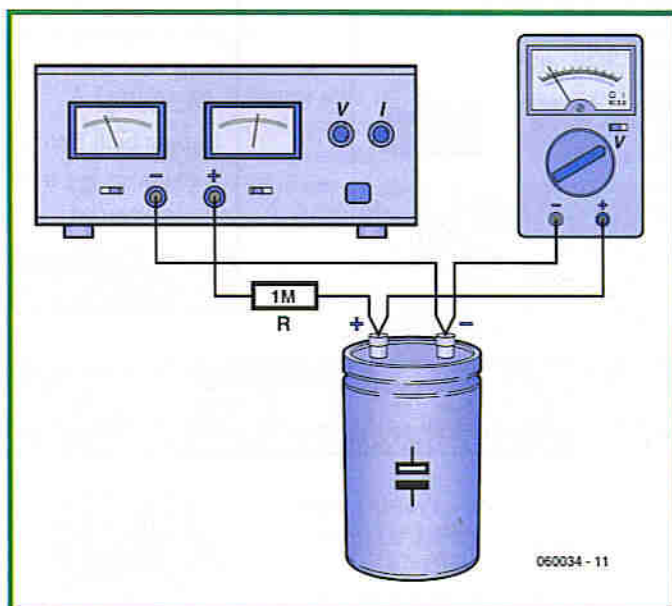
Reforming old electrolytic capacitors

Luc Lemmens

Electrolytic capacitors that have spent a long time in storage are being sold as 'new old stock' (NOS) by the surplus trade, or come from old equipment, are not or no longer of a suitable quality that allows them to be used just like that.

After manufacturing, there is a very thin layer of oxide on the positive electrode that acts as a dielectric between the plates. In normal use, when there is a voltage across the capacitor, this layer is maintained by the leakage current in this component. But if the capacitor is not used for a long time, this thin layer slowly disappears, so that the capacitor starts to look more like a short circuit. If a voltage is then suddenly applied, the current can rise so high that the capacitor overheats and the dielectric evaporates. This can result in the explosion of the capacitor.

At low values of capacitance it is not worth the trouble to take the risk because these components are not that expensive. Unless you want to restore, for example, an old radio, and want to keep it as original as possible. Also, axial capacitors are becoming increasingly rare



and are almost not available new. Large power supply reservoir capacitors have always been expensive and certainly in this category it is definitely worth the effort to try to breathe new life into them. And of course, it is this category that generates the most spectacular 'explosions' when something goes wrong...

This can be avoided by waking up the capacitor slowly (that is: reform the oxide layer slowly). Use a large value resistor (1 MΩ, for example) and connect it in series with the capacitor to a lab power supply. Start with a power supply voltage of about a quarter of the rated capacitor voltage and measure the voltage across the capacitor. It can take some time, even a number of hours before this voltage is equal to the power supply voltage (i.e., the capacitor is charged). It takes some patience to allow the oxide layer to be reformed. After that you can increase the voltage in a few steps to the rated value (each time wait until both voltages are equal again before proceeding). There is a reasonably good chance that this procedure will be successful if you follow this method with care and patience!

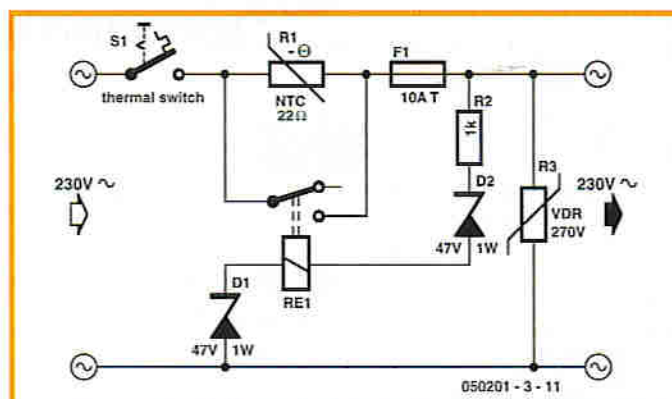
(060034-1)

Current surge limiter for toroidal transformers

K. Viernickel

Lots of circuit variations exist on this theme. We would like to add one more, however, that's not easily beaten for simplicity and reliability.

It seems that toroidal mains transformers can only be switched on by a hefty initial current. The current surge is especially high when initially the residual magnetism stored in the closed core has to be built up because of the instantaneous phase angle. The current surge occurs when the sinusoidal current in the primary winding and the remaining magnetism in the iron core cause the latter to go into saturation. An example



may help here. The residual magnetism has a positive value. When power is applied to the primary, a positive half cycle that

happens to arrive raises the positive magnetism value to a value sufficient to cause massive saturation of the iron core. In this condi-

tion, the only current limiter is the resistance of the primary winding copper wire, and that for sure is a very low value in the case of heavy toroidal transformers. Only after a few full cycles of the mains voltage will the magnetisation get synchronised with the alternating current, keeping the iron core free from saturation up to the nominal load limit. During the critical period, some kind of current limiting device should be used to prevent a big 'thump' at power-on. Here, a thermistor is used for that purpose.

In parallel with the NTC we find a normally-open relay contact. The contact will bypass the NTC after a short time, supplying the

transformer with the full mains voltage and of course allowing the NTC to cool down for the next power-on sequence. The relay will pull in as soon as the transformer is ready to accept the full mains voltage. The NTC is

protected by a resettable thermal switch and a 10-A slow-blow fuse.

The circuit has proved to be utterly reliable in practice. Besides a low component count, it is also marked by low current consump-

tion. Of course, it will cause a short power-on delay.

The value of resistor R2 and zener diode D2 may have to be adapted to suit the coil voltage of RE1.

(050201-3)

Warning.

This circuit is connected directly the mains voltage. All relevant precautions apply in respect of electrical safety.

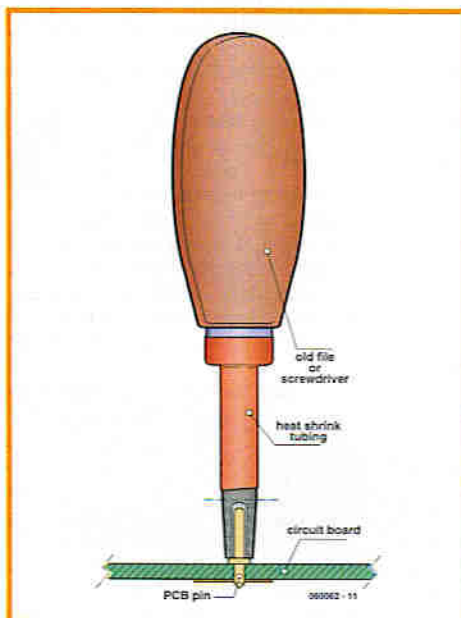
PCB pin insertion tool

Luc Lemmens (Elektor labs)

The humble PCB pin is used not only to connect wires to PCB tracks, but also for test and measurements points on circuit boards. Despite their mechanical simplicity, PCB pins are surprisingly difficult to mount and solder. Frequently encountered problems (admit it!) are burnt fingers while soldering the pin, and pins dropping from the board when the board is turned, or, worse, when they're being soldered. Try to keep it in place with your finger — too hot to touch — look for pliers — pin dislocated — and so on.

It's a good idea to drill the holes for the PCB pins a fraction smaller than the pin diameter — that way, the pin remains in place

when you're ready to solder it. However, that also requires a bit more force to push the pin into position and a tool is then useful to prevent injuring your fingers. Pliers may be less suitable, especially if considerable force is required on the pin. To the best of our knowledge, no commercial tool exists for the purpose. No problem, let's make a PCB pin insertion tool ourselves.



A discarded round file or screwdriver is great. Cut or grind the shaft as straight as you can and drill a hole in the end so the ridge on the PCB pin is secure against the surface of the tool. The PCB pin is inserted into the tool and held in place with a nail or fingertip. The tool handle provides a secure grip and allows considerable insertion force to be applied. If an old file is used, it is recommended to cover the remaining section of the steel surface with heat shrink tubing. This will prevent injury to your hand.

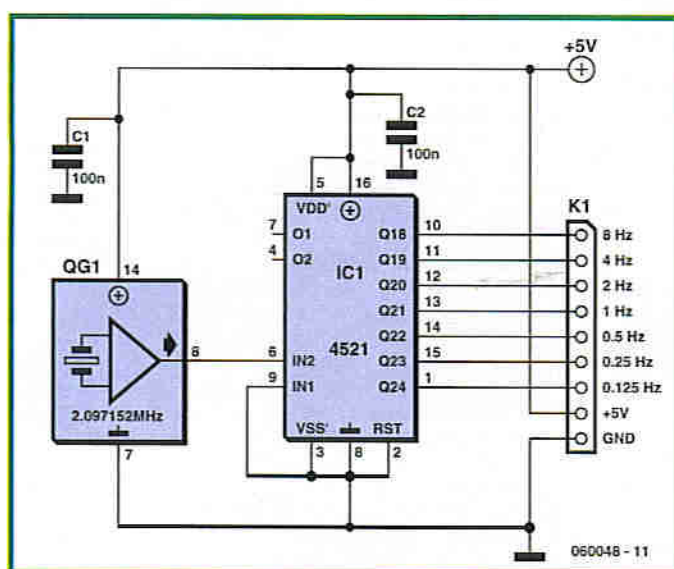
(050062-1)

Accurate timebase

Thomas Pototschnig

This circuit demonstrates how easily a timebase can be designed using a minimum number of components. This circuit consists of no more than an IC and an oscillator to which a few connections and decoupling parts are added. Use is made of a single IC from the 4000 series, the type 4521 oscillator / counter with 24 steps. Here we only use the counter section of the IC.

The IC is supplied with a clock signal by an oscillator module. The clock signal is divided down by the 4521 to obtain certain values. Discrete frequencies obtained in this way are available on the counter output pins of the 4521. For example, pin 10 (Q18) supplies the clock frequency (applied to pin 6) by a factor of 2^{18} or 262,144. Like-



- Pin 10 (Q18): 8 Hz;
- Pin 11 (Q19): 4 Hz;
- Pin 12 (Q20): 2 Hz;
- Pin 13 (Q21): 1 Hz;
- Pin 14 (Q22): 0.5 Hz;
- Pin 15 (Q23): 0.25 Hz;
- Pin 1 (Q24): 0.125 Hz.

In case other frequencies are required, a different crystal oscillator module should be selected. For flexibility, an IC socket is recommended so modules can be exchanged quickly. Alternatively, modules may be connected to the 4521 by means of a selector switch.

To keep the circuit as versatile as possible, the outputs of the 4521 counter may be made available for connection to the outside world by way of a pinheader. For the sake of convenience, the pinheader also supplies +5 V and GND.

(050048-1)

wise, pin 1 (Q24) divides the input signal by 2^{24} or 16,777,216.

By using a clock frequency of

2.097152 MHz the following timebase frequencies are obtained at the output of the 4521:



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Kit Order Code: 3166KT - £15.95

Assembled Order Code: AS3166 - £25.95

DC Motor Speed Controller (5A/100V)

Control the speed of almost any common DC motor rated up to 100V/5A. Pulse width modulation output for maximum motor torque at all speeds. Supply: 5-15Vdc. Box supplied.

Dimensions (mm): 60Wx100Lx60H.

Kit Order Code: 3067KT - £12.95

Assembled Order Code: AS3067 - £20.95

NEW! PC / Standalone Unipolar Stepper Motor Driver

Drives any 5, 6 or 8-lead unipolar stepper motor rated up to 6 Amps max. Provides speed and direction control. Operates in stand-alone or PC-controlled mode. Up to six 3179 driver boards can be connected to a single parallel port. Supply: 9Vdc. PCB: 80x50mm.

Kit Order Code: 3179KT - £11.95

Assembled Order Code: AS3179 - £19.95

NEW! Bi-Polar Stepper Motor Driver

Drive any bi-polar stepper motor using externally supplied 5V levels for stepping and direction control. These usually come from software running on a computer.

Supply: 8-30Vdc. PCB: 75x65mm.

Kit Order Code: 3158KT - £14.95

Assembled Order Code: AS3158 - £29.95

Most items are available in kit form (KT suffix) or assembled and ready for use (AS prefix).

Controllers & Loggers

Here are just a few of the controller and data acquisition and control units we have. See website for full details. Suitable PSU for all units: Order Code PSU345 £9.95

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Assembled Order Code: AS3180 - £47.95

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Kit Order Code: 3145KT - £17.95

Assembled Order Code: AS3145 - £23.95

Additional DS1820 Sensors - £3.95 each

NEW! DTMF Telephone Relay Switcher

Call your phone number using a DTMF phone from anywhere in the world and remotely turn on/off any of the 4 relays as desired. User settable Security Password, Anti-Tamper, Rings to Answer, Auto Hang-up and Lockout. Includes plastic case. Not BT approved. 130x110x30mm. Power: 12Vdc.

Kit Order Code: 3140KT - £44.95

Assembled Order Code: AS3140 - £64.95

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Assembled Order Code: AS3108 - £64.95

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Assembled Order Code: AS3149E - £52.95



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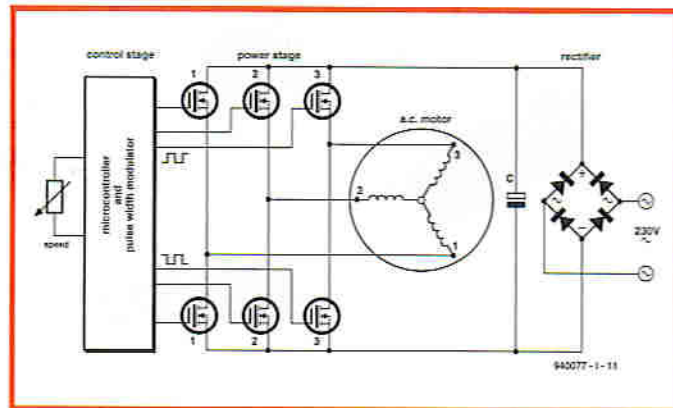


1-to-3 Phase Converter (1994/1995)

Jan Buiting

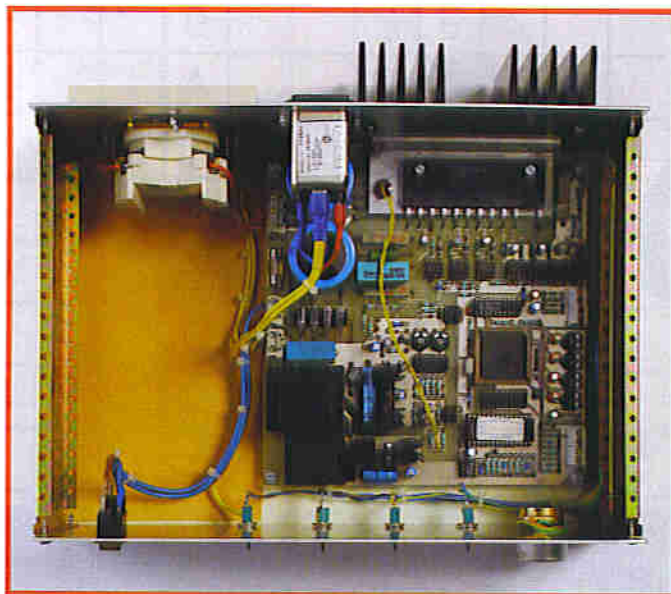
Our resident designer Karel Walraven has been known for almost three decades to have a serious infatuation with electric motors and it was no wonder he was assigned, back in 1994, to a project received from one B. Yahya for a 1-to-3 phase converter. Unlike his colleagues (and myself) safe in the world of milli-amps and everything sub 20 volts or so, Karel likes kVAs, big a.c. motors and 'electrical engineering' in general (although he will also happily whip up a piece of 8051 assembly code for you). From the very beginning, the phase converter project raised high hopes as back in 1994 such units were rarer than hens' teeth and only found in the professional domains, i.e., well out of the reach of the DIY enthusiast. So what's the point in converting your 230-V 1-phase mains voltage to three phases? The answer is: none, unless you have a really fine 3-phase motor lying about you'd like to apply speed control on. Three-phase motors are relatively powerful per watt of energy absorbed and therefore the items of choice in lots of professional equipment. The principle underlying the ability to control a 3-phase motor for speed is illustrated by the **block schematic**. It is based on the fact that the speed of a 3-phase motor depends on the frequency of the applied voltage rather than the voltage level. In our design, a hefty control circuit through some power MOSFETs applies almost sinusoidal voltages across the motor windings connected in 'star' arrangement. The sinusoidal voltage was created using pulse-width modulation.

Without delving into the operation of the design, two things must have struck our readers as quite novel at the time: firstly, the use of an 80C535 microcontroller (not easily associated with 750-watt a.c. motors) and sec-



ondly, the sudden appearance of a GAL of the 20-legged variety. The GAL, in the end, caused the most concern as it was a rela-

tively new component in 1994. Of course, we supplied it ready-programmed, but lots of readers started asking for the jedec file to



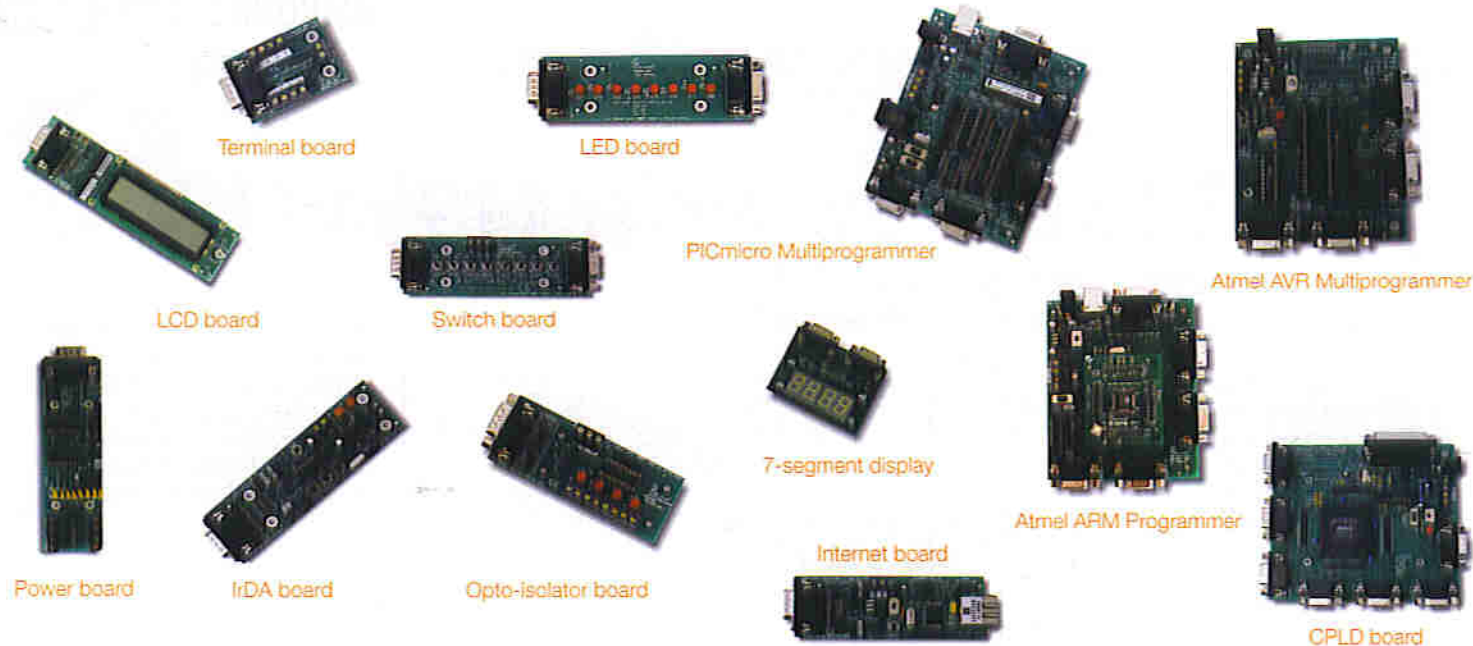
burn their own 16V8. I remember some readers accusing us of black-box engineering on account of the GAL being a key component they could not easily produce at home. Some even claimed it 'did nothing except filling Elektor's pockets', but when shown the equivalent in logic gates the critics soon shut up.

The converter was so complex, and there was so much to say about it, the article had to be split in two parts. The unit graced the magazine cover in December 1994 and its construction was described in January 1995. A good deal of attention was given to electrical safety aspects of the project.

When I pulled the unit from cabinet #12 in our laboratory it struck me that a motor or two would be nice to photograph with the converter. Karel opened a drawer and handed me three mint looking motors which, he said, had been in use by the Dutch State Mines (DSM) in the late 1960s (I thought they couldn't have been older than a few years). I was in for another surprise: the motors were the ones originally pictured on the December 1994 magazine cover.

Having been told about this month's subject for Retronics my colleague Guy Raedersdorf in the French editorial department suddenly remembered having received a letter from an irate reader from a North-African country. Not mincing his French, the correspondent condemned Elektor & staff for All Eternity on account of having printed the name of an author he was at loggerheads with regarding some religious interpretation. The wretched author, it turned out, was Harun Yahya — not even a distant relative of the designer of the Elektor project. Twelve years on I can safely say that the converter was a very popular project and we are no longer waiting for whatever curse of to fall upon us. Or maybe it was that virus in last week's email?

(065034-1)



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Hexadoku

Puzzle with an electronic touch

Here is our Hexadoku puzzle for the month of May. Switch off the PC and sharpen your pencil for another brain teaser that'll turn out to be a real challenge to solve.

Send us your solution and win one of the fantastic prizes!

The instructions for the puzzle are straightforward. In the diagram composed of 16x16 boxes, enter numbers in such a way that **all** hexadecimal numbers 0 through F (that's 0-9 and A-F) occur once in every row, once in every column, and in every one of the 4x4 boxes (marked by the thicker black lines). A number of clues are given in the puzzle

and these determine the start situation.

Your solution may win a prize and requires only the numbers in the grey boxes to be sent to us (see below). The puzzle is also available as a **free download** from our website (Magazine → 2006 → May).

(065042-1)

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | | | 3 | 5 | | | A | 8 | E | 2 | 4 | | D | C | |
| D | 4 | | | | | | | | | | | | | | 0 |
| B | 5 | 1 | 6 | | | 2 | | F | | 9 | | 8 | | | |
| | | | | | 7 | | 8 | 6 | 0 | | D | 2 | | | B |
| E | 0 | | | A | 9 | 3 | 7 | | 6 | | | | | | |
| | 1 | | C | | F | | | 0 | | | 5 | E | | | |
| 4 | F | | | C | 2 | | 1 | A | | | | | 6 | D | |
| | 6 | | 2 | | | 0 | D | 7 | | | | A | B | 5 | 4 |
| | | 6 | | 1 | | 8 | 0 | C | 9 | | | | | | F |
| | C | | 7 | 6 | A | | E | | | 8 | 3 | 2 | | D | |
| 8 | B | 4 | 9 | 7 | | | | E | F | | | | 0 | 6 | |
| 3 | | | | 9 | 4 | | F | 2 | | | | 7 | 1 | | |
| | | E | | D | | A | | | | | 1 | 6 | | 0 | C |
| | 9 | | 4 | | | | C | | 2 | | 0 | | 8 | 3 | |
| | | B | | | | | | D | | A | E | | | F | 1 |
| A | | | 1 | F | | | | 3 | 7 | 6 | | B | 5 | E | |

Entering the competition

Please send the numbers in the grey boxes by email, fax or post to

Elektor Electronics Hexadoku
Regus Brentford
1000 Great West Road
Brentford TW8 9HH
United Kingdom.
Fax (+44) (0)208 2614447
Email:
editor@elektor-electronics.co.uk
Subject: hexadoku 05-2006.

The closing date is 24 May 2006.
Competition not open to employees of
Segment b.v., its business partners
and/or associated publishing houses.

Prize winners

The solution of the February 2006 Hexadoku is: 3B479.
The **E-blocks Starter Kit Professional** goes to:
Steve Barber
(Stotfold, UK).

An Elektor SHOP Voucher worth £35.00

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Jari Koskinen (Koulova, FIN),
R. Wilton (Helston, UK) and
Jim Gray (Jefferson, USA).

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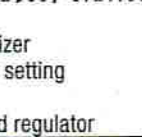


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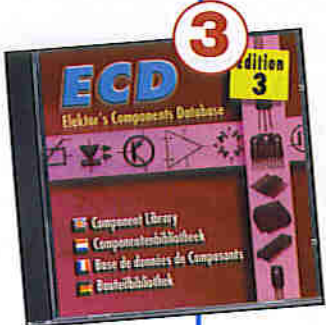
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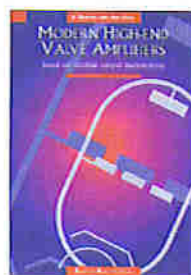
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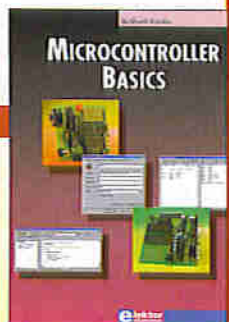
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(June 2005)

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040264-71

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Electrosmog Tester

(June 2005)

Ready-built PCB

(excl. enclosure)

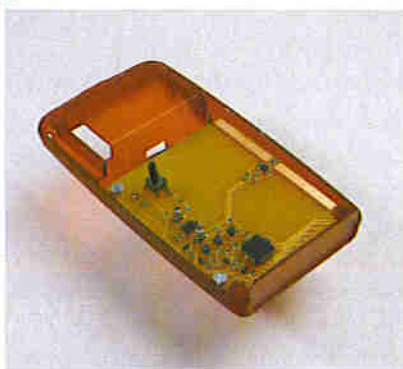
050008-91

£ 50.00 / \$ 94.25

Matching enclosure

050008-71

£ 10.25 / \$ 19.30



OBD-2 Analyser

(July/August 2005)

Kit of parts including PCB, programmed controller, components (including IC7 ; IC3 = PCA82C250, 12 V), enclosure and RS232 cable. OBD cable not included.

050092-71

£ 52.50 / \$ 96.95

OBD cable

050092-72

£ 27.55 / \$ 51.95



ESR/C Meter

(September 2005)

Kit of parts including PCB, default LCD module, 2x16 characters and programmed controllers. Enclosure not included.

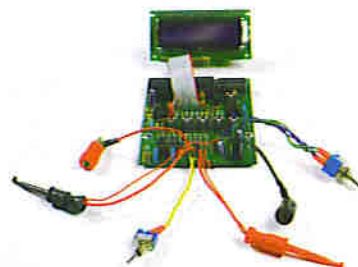
040259-71

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Matching enclosure

040259-72

£ 6.99 / \$ 12.95



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Electrosmog Tester

050008-91 PCB, ready built and tested 50.00 94.25

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010208-91 ready-assembled PCB incl. software, cable, adapter & related articles 69.00 112.50

Gameboy Digital Sampling Oscilloscope (GBDSO)

990082-91 ready-assembled board, incl. the PC software and related articles 103.00 183.00

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040444-91 Processor board, ready-made and tested 25.50 48.05

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030060-91 Microprocessor Board, ready-assembled 75.90 142.95

044026-91 Network Extension Board, ready-assembled 44.50 83.95

044026-92 Combined package (030060-91 & 044026-91 & related articles) 117.50 220.95

NO. 354 MAY 2006

Onboard OBD-2 Analyser

050176-73 LCD, 4x20 characters with backlight 13.77 25.94

050176-72 Kit of parts, incl. 050176-1, 050176-2, 050176-42, all components, excl. LCD 7.25 13.65

050176-74 Case, Bopla Unimas 160 with Perspex cover and mounting plate 25.50 48.05

050176-42 ATmega16, programmed 10.30 19.45

050092-71 Kit of parts without cable 52.50 96.95

050092-72 DB9 to OBD adapter cable 27.55 51.95

Mini ATmega Board

050176-1 PCB, includes adapter PCB 050176-2 8.95 16.85

NO. 353 APRIL 2006

Simple rechargeable A Cell Analyser

050394-1 PCB, bare 4.80 9.04

050394-11 Disk, PC Software 5.18 9.75

Universal SPI Box

050198-41 AT89C2051-24PC, Programmed 7.25 13.65

NO. 352 MARCH 2006

Application Board for R8C/13

050179-92 Ready-assembled board 48.27 90.94

| | | | |
|-----------|--------------------|-------|-------|
| 050179-1 | PCB | 13.77 | 25.94 |
| 030451-72 | LCD with backlight | 7.25 | 13.65 |
| 030451-73 | Poly-LED display | 25.50 | 48.05 |

FPGA-Prototyping board

| | | | |
|-----------|-----------------------|--------|--------|
| 050370-91 | Ready assembled board | | |
| | For subscribers | 171.80 | 323.50 |
| | For non-subscribers | 206.30 | 388.50 |

Telephone Eavesdropper

| | | | |
|----------|-----|------|-------|
| 030379-1 | PCB | 9.05 | 17.05 |
|----------|-----|------|-------|

Versatile FPGA Module

| | | | |
|-----------|--------------------------------|--------|--------|
| 040477-91 | Ready assembled plug-on module | | |
| | For subscribers | 171.80 | 323.50 |
| | For non-subscribers | 206.30 | 388.50 |

NO. 351 FEBRUARY 2006

Brushless Motor Controller

| | | | |
|-----------|--------------------|------|------|
| 050157-41 | ST7MC1, programmed | 3.80 | 7.15 |
|-----------|--------------------|------|------|

A 16-bit Tom Thumb

| | | | |
|-----------|-----------------|------|-------|
| 050179-91 | R8C Starter Kit | 8.30 | 15.60 |
|-----------|-----------------|------|-------|

NO. 350 JANUARY 2006

95-watt Laptop PSU Adaptor

| | | | |
|----------|-----|------|------|
| 050029-1 | PCB | 4.80 | 9.05 |
|----------|-----|------|------|

Automatic Attic Window Controller

| | | | |
|-----------|-----------------------------|-------|-------|
| 050139-11 | Disk, PIC source & hex code | 5.20 | 9.75 |
| 050139-41 | PIC16F84A-20/P, programmed | 13.10 | 24.65 |
| 030451-72 | LCD Module 2x16 characters | 7.25 | 13.65 |
| 030451-73 | PLED Module 2x16 characters | 25.50 | 48.05 |

SMD Reflow Soldering Oven

| | | | |
|-----------|-----------------------------|-------|-------|
| 050319-11 | Disk, source and hex code | 5.20 | 9.75 |
| 050319-41 | AT89C52/24J1, programmed | 7.60 | 14.25 |
| 030451-72 | LCD Module 2x16 characters | 7.25 | 13.65 |
| 030451-73 | PLED Module 2x16 characters | 25.50 | 48.05 |

Timer Switch for Washing Machine

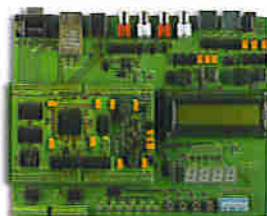
| | | | |
|-----------|-----------------------------|-------|-------|
| 050058-1 | PCB | 8.90 | 16.70 |
| 050058-11 | Disk, PIC source & hex code | 5.20 | 9.75 |
| 050058-41 | PIC16F84, programmed | 13.10 | 24.65 |

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FPGA Project Bundle (FPGA Module & FPGA Prototyping Board) (March 2006)

Ready-assembled Versatile FPGA Module:

- Altera Cyclone FPGA (12,060 LE's!)
- 4 Mbit configuration RAM
- 8 Mbit user RAM (20nS!)
- 1 Mbit user FLASH memory
- 80 user I/O lines
- 1 dedicated fast clock input
- 4 dedicated PLL outputs
- integrated power supply unit
- 50MHz oscillator



A 16-bit Tom Thumb (February 2006)

R8C Starter Kit comprising CD-ROM and R8C/13 microcontroller board with SIL pinheaders supplied separately.



050179-91

£ 8.30 / \$ 15.60

NO. 349 DECEMBER 2005

From A to D via USB

| | | | |
|-----------|---------------------|------|-------|
| 050222-1 | PCB | 7.95 | 14.95 |
| 050222-41 | IOW24-P, programmed | 9.40 | 17.75 |

Telephone Supervisor

| | | | |
|-----------|--|------|-------|
| 050039-41 | PIC16F628-20/P, programmed | 8.20 | 15.55 |
| 050039-81 | CD-ROM, PIC hex & source codes, LCM First Server | 6.90 | 12.95 |

NO. 348 NOVEMBER 2005

Remote Control by Mobile Phone

| | | | |
|-----------|------------------------------|-------|-------|
| 040415-1 | PCB | 6.20 | 11.65 |
| 040415-11 | Disk, PIC source & hex files | 5.20 | 9.75 |
| 040415-41 | PIC16F84A-20/P, programmed | 10.30 | 19.50 |

Synchronous Servos

| | | | |
|-----------|----------------------------|------|-------|
| 020031-11 | Disk, project software | 5.20 | 9.75 |
| 020031-41 | AT90S2313-10PC, programmed | 7.85 | 14.85 |

NO. 347 OCTOBER 2005

27C512 Emulator

| | | | |
|-----------|-------------------------------|-------|-------|
| 030444-11 | Disk, project software | 5.20 | 9.75 |
| 030444-31 | EPROM7064SLC84-15, programmed | 27.50 | 51.95 |
| 030444-41 | AT90S8515-APC, programmed | 15.10 | 28.35 |

Colossus Jr.

| | | | |
|-----------|---------------------------|------|------|
| 040267-11 | Disk, PIC source code | 5.20 | 9.75 |
| 040267-41 | PIC12F675-C/P, programmed | 4.10 | 5.35 |

Flash Lock for PCs

| | | | |
|-----------|-----------------------------|------|-------|
| 050107-41 | PIC16F628A-I/SO, programmed | 5.00 | 9.45 |
| 050107-81 | CD-ROM, project software | 6.90 | 12.95 |

NO. 346 SEPTEMBER 2005

ESR/C Meter

| | | | |
|-----------|--------------------------------|-------|--------|
| 040259-1 | PCB, bare | 12.40 | 23.35 |
| 040259-11 | Disk, PIC source & hex codes | 5.20 | 9.75 |
| 040259-41 | PIC16F877-20/P, programmed | 15.50 | 29.25 |
| 040259-42 | PIC16F84A-20/P, programmed | 10.30 | 19.45 |
| 040259-71 | kit of parts without enclosure | 63.99 | 119.95 |
| 040259-72 | matching enclosure | 6.99 | 12.95 |

Hitting the High Note

| | | | |
|-----------|--------------------------|-------|-------|
| 040015-41 | ATmega8-16PC, programmed | 15.50 | 29.25 |
|-----------|--------------------------|-------|-------|

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The Versatile FPGA Module (no. 040477-91) and the FPGA Prototyping Board (no. 050370-91) are also available individually. See www.elektor-electronics.co.uk for more details.

Application Board for R8C/13 (March 2006)

Extends R8C/13 micro module with 2 x serial I/O, USB, LCD, LEDs, analogue I/P, PSU and, reset and MODE control.



Ready built PCB

050179-92

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LCD with backlight

030451-72

£ 7.25 / \$ 13.65

Poly-LED display

030451-73

£ 25.50 / \$ 48.05

| | | | |
|-----------|------------------------|-------|-------|
| 040015-11 | Disk, project software | 5.20 | 9.75 |
| 040313-11 | Disk, project software | 5.20 | 9.75 |
| 040313-41 | PIC16F876, programmed | 16.55 | 31.15 |
| 040313-1 | PCB | 7.55 | 14.25 |

Racetrack Timer

| | | | |
|-----------|-------------------------|------|-------|
| 040395-41 | AT89C2051-24PI | 6.85 | 12.95 |
| 040395-81 | CDROM, project software | 5.15 | 9.75 |

NO. 345 JULY/AUGUST 2005

1 MHz Frequency Counter

| | | | |
|-----------|----------------------------|------|-------|
| 030045-11 | Disk, project software | 5.20 | 9.75 |
| 030045-41 | AT90S2313-10PI, programmed | 5.50 | 10.35 |

Code Lock with One Button

| | | | |
|-----------|--------------------------|------|-------|
| 040481-11 | Disk, source & hex files | 5.20 | 9.75 |
| 040481-41 | PIC16F84, programmed | 6.85 | 12.95 |

Digital VU Meter

| | | | |
|-----------|------------------------|------|------|
| 050118-11 | Disk, Attiny software | 5.20 | 9.75 |
| 050118-41 | Attiny 15L, programmed | 3.40 | 6.45 |

DIL/SOIC/TSSOP Adapter Boards

| | | | |
|----------|--------------------------|------|-------|
| 040289-1 | PCB, for 20-way DIL IC | 6.75 | 12.70 |
| 040289-2 | PCB, for 20-way SOIC IC | 6.75 | 12.70 |
| 040289-3 | PCB, for 20-way TSSOP IC | 6.75 | 12.70 |

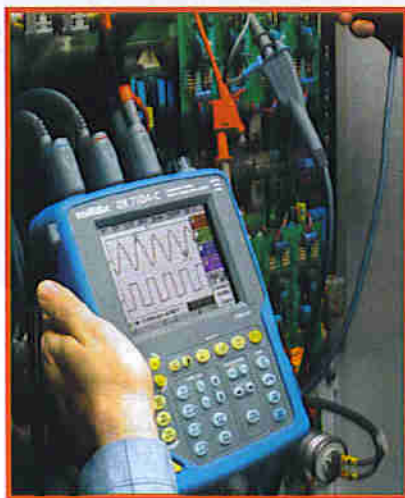
MP3 Adaptor for TV

| | | | |
|-----------|-------------------------------|-------|-------|
| 054035-1 | PCB, bare | 3.95 | 7.50 |
| 054035-11 | Disk, project software | 5.20 | 9.75 |
| 054035-31 | EPROM7064SLC44-10, programmed | 27.55 | 51.95 |

OBD-2 Analyser

| | | | |
|-----------|----------------------------|-------|-------|
| 050092-1 | PCB, bare | 8.95 | 16.85 |
| 050092-41 | T89C51CC02UA, programmed | 26.20 | 49.40 |
| 050092-71 | Kit of parts without cable | 52.50 | 96.95 |
| 050092-72 | DB9 to OBD adapter cable | 27.55 | 51.95 |

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home construction = fun and added value



Scopemeters Compared

Everyone serious about electronics as a profession but also as a pastime will need to use an oscilloscope from time to time. The conventional oscilloscope is usually powered from the mains and designed to stay on the test bench for most of its useful lifetime. By contrast, a new generation of instruments called scopemeters is designed for portability and use 'in the field'. In the next issue we will provide a market overview of available instruments.

Electronic Passports

If your passport runs out in the next few months the chances are you could be issued with one of the new electronic passports that are being introduced throughout the EU this year. ePassports have an embedded RFID tag containing your personal information which Immigration officials can read remotely; hopefully nobody else will be eavesdropping on this electronic conversation...

Theme Plan for 2006

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|-------------|-------|---------------------------------|
| January | | Recycling / Reverse Engineering |
| February | | Motors / Propulsion |
| March | | Development / Microcontrollers |
| April | | Power Supplies / Safety |
| May | | Soldering / Etching |
| June | | Test & Measurement |
| July/August | | Summer Circuits |
| September | | RFID / Medical Electronics |
| October | | E-Simulation |
| November | | Chipcards / Security |
| December | | Electromechanical / Enclosures |

Also...

Lambda Probes;
PCB Short Circuit Locator;
FM Stereo Test Transmitter;
FPGA Course (3);
E-blocks for
X10 Networks;
Hexadoku Puzzle.

Network Cable Tester

Computer networks are not just found in offices but also in private homes, albeit at a smaller scale in most cases. Everything's just fine as long as the network does what it's supposed to do, but when problems start to occur, a good tester is in order to pinpoint the cable or connection that needs to be replaced. In our design for such a tester, a PIC 16F874 checks the four wire pairs for proper connectivity, showing the result on four LEDs. A separate switch allows (Gigabit) cross-over cables to be tested as well.



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January 2006

New

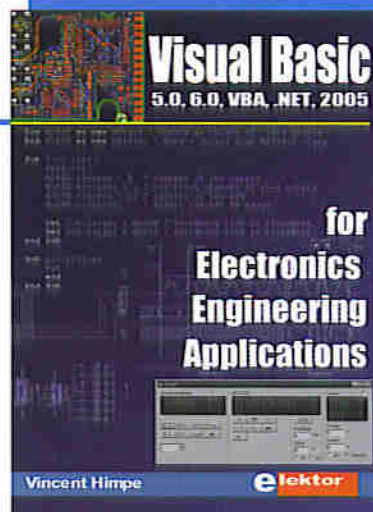
Visual Basic for Electronics Engineering Applications

This book is targeted towards those people that want to control existing or home made hardware from their computer. After familiarizing yourself with Visual Basic, its development environment and the toolset it offers are discussed in detail. Each topic is accompanied by clear, ready to run code, and where necessary, schematics are provided that will get your projects up to speed in no time.

This book discusses tools like Debug to find hardware addresses, setting up remote communication using TCP/IP and UDP sockets, writing your own internet servers and even connecting your own block of hardware over USB or Ethernet and controlling it from Visual Basic.

All examples are ready to compile using Visual Basic 5.0, 6.0, NET or 2005. Extensive coverage is given on the differences between what could be called Visual Basic Classic and Visual basic .NET / 2005.

ISBN 0-905705-68-8
496 pages
£27.50 / US\$ 51.50



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